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DISCRIMINATION LEARNING SITUATIONS

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-64-192

JANUARY 1964

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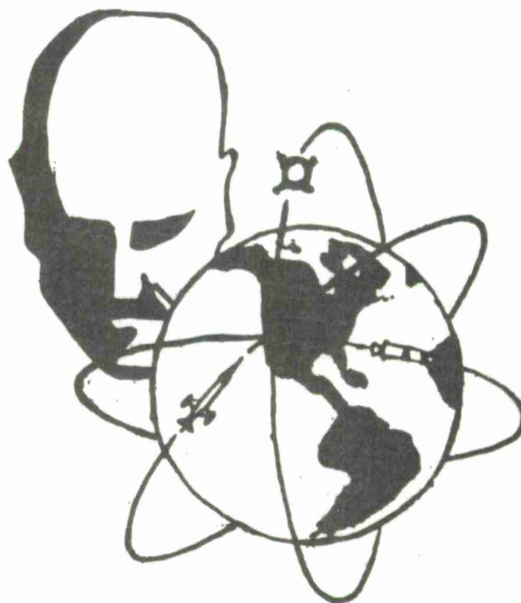
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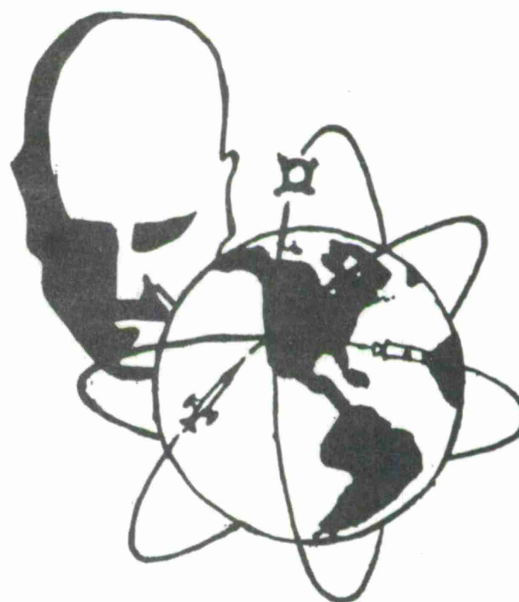
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ABSTRACT

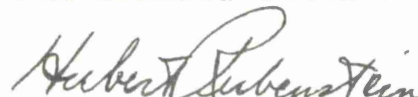
A decision-theoretic analysis and experiment of three related choice situations is presented. The first situation is a standard probabilistic discrimination learning task. Each trial begins with the presentation of one of a set of stimuli. The subject must choose between two response alternatives to predict which of two events will occur on the trial, the probability of each event being a function of the stimulus presented. The second situation arises when the conditional probabilities, i.e., the probabilities of the stimuli given the events, are introduced to the subject at the beginning of the experiment. The third situation is like the second except for the fact that the subject is not told which event occurs on each trial.

The decision-theoretic analysis shows what differences in performance would be expected among the three conditions when a strategy which maximizes average expected payoff is employed.

One group of subjects was run in each situation with the overall relative frequency of one event equal to .80. The performance of the subjects in the first and second situations was virtually identical, while the performance of the subjects in the third (non-feedback) was somewhat worse. The performance measure was the sum of the differences between the objective expected payoff of the optimal choices and the choices made by the subject. Comparisons of the choice proportions for the first and second groups indicated that subjects in the second group did not integrate information concerning the overall relative frequencies of events and conditional probabilities. A large proportion of subjects in the third (non-feedback) group made every choice in agreement with the assumption that the overall relative frequency of one event was one-half.

PUBLICATION REVIEW AND APPROVAL

This Technical Documentary Report has been reviewed and is approved.


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TABLE OF CONTENTS

KEY WORD LIST	v
LIST OF FIGURES	vi
LIST OF TABLES	ix
ACKNOWLEDGEMENTS	x
Chapter	
I. INTRODUCTION	1
II. DESIGN OF EXPERIMENT	10
III. EXPERIMENTAL METHOD	19
IV. RESULTS	26
V. DISCUSSION AND SUMMARY	59
APPENDIX I	68
APPENDIX II	75
APPENDIX III	84
REFERENCES	105

KEY WORD LIST

1. DECISION MAKING
2. BEHAVIOR
3. VERBAL BEHAVIOR
4. GAME THEORY
5. LEARNING
6. ANALYSIS

LIST OF TABLES

Table	Page
1. THEORETICAL CONDITIONAL, MARGINAL, AND POSTERIOR PROBABILITIES, AND OBSERVED MARGINAL PROBABILITIES-- $\pi_0 = .80$, $p_0 = .65$, $p_1 = .40$, $n = 5$	21
2. PROPORTION OF S_s CHOOSING E_0 ON THE FIRST 11 TRIALS	54

LIST OF FIGURES

Figure	Page
1. CUMULATIVE REGRET FUNCTION FOR EACH GROUP AND FOR OPTIMAL MODEL FOR EACH CONDITION, GROUP CC (N = 48), GROUP CP-CC (N = 57) and GROUP CP- <u>CC</u> (N = 57)	28
2. CUMULATIVE REGRET FUNCTIONS EVALUATED AT 5-TRIAL INTERVALS FOR GROUPS CC-FF (N = 19), CP-FI (N = 10, and CC-II (N = 19). THE FUNCTION LABELED "MODEL" WAS GENERATED BY THE OPTIMAL MODEL FOR GROUP CC	33
3. CUMULATIVE REGRET FUNCTION EVALUATED AT 5-TRIAL INTERVALS FOR GROUPS CP-CC-FF (N = 12), CP-CC-FI (N = 12), CP-CC-II (N = 23) and CP-CC-FIG. (N = 10). THE FUNCTION LABELED "MODEL" IS GENERATED BY THE OPTIMAL MODEL FOR GROUP CP-CC WITH $\alpha = \beta = 25$	34
4. CUMULATIVE REGRET FUNCTION EVALUATED AT 5-TRIAL INTERVALS FOR GROUPS CP- <u>CC</u> -II (N = 24) AND CP- <u>CC</u> -FIG. (N = 32).	37
5. CUMULATIVE REGRET FUNCTION FOR GROUPS CC-FF (N = 19), CP-CC-FF (N = 12), CC-FI (N = 10) CP-CC-FI (N = 12), CC-II (N = 19), CP-CC-II (N = 23)	39
6. PROPORTION OF Ss MAKING OPTIMAL CHOICE FOR SYMPTOMS HEADACHE, SORE THROAT, AND BACKACHE. GROUPS CC-FF (N = 19) and CP-CC-FF (N = 12). THE TRIALS ON WHICH E ₁ OCCURRED ARE MARKED NEAR THE BOTTOM OF THE FIGURES.	40
7. PROPORTION OF Ss MAKING OPTIMAL CHOICE FOR SYMPTOM NAUSEA. GROUPS CC-FF (N = 19) and CP-CC-FF (N = 12). THE TRIALS ON WHICH E ₁ OCCURRED ARE MARKED NEAR THE BOTTOM OF THE FIGURE	41

LIST OF FIGURES--(Continued)

Figure	Page
8. PROPORTION OF Ss MAKING OPTIMAL CHOICE FOR SYMPTOM FEVER. GROUPS CC-FF (N = 19) and CP-CC-FF (N = 12). THE TRIALS ON WHICH E ₁ OCCURRED ARE MARKED NEAR THE BOTTOM OF THE FIGURE.	42
9. PROPORTION OF Ss MAKING OPTIMAL CHOICE FOR SYMPTOM DROWSINESS. GROUPS CC-FF (N = 19) and CP-CC-FF (N = 12). THE TRIALS ON WHICH E ₁ OCCURRED ARE MARKED NEAR THE BOTTOM OF THE FIGURE.	43
10. PROPORTION OF Ss MAKING OPTIMAL CHOICE FOR SYMPTOMS HEADACHE, SORE THROAT, AND BACKACHE. GROUPS CC-FI (N = 10) AND CP-CC-FI (N = 12). THE TRIALS ON WHICH E ₁ OCCURRED ARE MARKED NEAR THE BOTTOM OF THE FIGURE	45
11. PROPORTION OF Ss MAKING OPTIMAL CHOICE FOR SYMPTOM NAUSEA. GROUPS CC-FI (N = 10) AND CP-CC-FI (N = 12) THE TRIALS ON WHICH E ₁ OCCURRED ARE MARKED NEAR THE BOTTOM OF THE FIGURE.	46
12. PROPORTION OF Ss MAKING OPTIMAL CHOICE FOR SYMPTOM FEVER. GROUPS CC-FI (N = 10) AND CP-CC-FI (N = 12) THE TRIALS ON WHICH E ₁ OCCURRED ARE MARKED NEAR THE BOTTOM OF THE FIGURE...	47
13. PROPORTION OF Ss MAKING OPTIMAL CHOICE FOR SYMPTOM DROWSINESS. GROUPS CC-FI (N = 10) AND CP-CC-FI (N = 12). THE TRIALS ON WHICH E ₁ OCCURRED ARE MARKED NEAR THE BOTTOM OF THE FIGURE.	48
14. PROPORTION OF Ss MAKING OPTIMAL CHOICE FOR SYMPTOMS HEADACHE, SORE THROAT, AND BACKACHE. GROUPS CC-II (N = 19) AND CP-CC-II (N = 23). THE TRIALS ON WHICH E ₁ OCCURRED ARE MARKED NEAR THE BOTTOM OF THE FIGURE.	49
15. PROPORTION OF Ss MAKING OPTIMAL CHOICE FOR SYMPTOM NAUSEA. GROUPS CC-II (N = 19) AND CP-CC-II (N = 23) THE TRIALS ON WHICH E ₁ OCCURRED ARE MARKED NEAR THE BOTTOM OF THE FIGURE.	50

LIST OF FIGURES--(Continued)

Figures	Page
16. PROPORTION OF S_s MAKING OPTIMAL CHOICE FOR SYMPTOM FEVER. GROUPS CC-II (N = 19) AND CP-CC-II (N = 23). THE TRIALS ON WHICH E_1 OCCURRED ARE MARKED NEAR THE BOTTOM OF THE FIGURE	51
17. PROPORTION OF S_s MAKING OPTIMAL CHOICE FOR SYMPTOM DROWSINESS. GROUPS CC-II (N = 19) AND CP-CC-II (N = 23). THE TRIALS ON WHICH E_1 OCCURRED ARE MARKED NEAR THE BOTTOM OF THE FIGURE	52
18. PROPORTION OF S_s MAKING OPTIMAL CHOICE FOR SYMPTOMS HEADACHE, SORE THROAT, AND BACKACHE. GROUP CP-CC-II (N = 24). THE DASHED LINES ARE THE CP MATCHING LINES.	55
19. PROPORTION OF S_s MAKING OPTIMAL CHOICE FOR SYMPTOM NAUSEA. GROUP CP-CC-II (N = 24). THE DASHED LINE IS THE CP MATCHING LINE	56
20. PROPORTION OF S_s MAKING OPTIMAL CHOICE FOR SYMPTOM FEVER. GROUP CP-CC-II (N = 24). THE DASHED LINE IS THE CP MATCHING LINE	57
21. PROPORTION OF S_s MAKING OPTIMAL CHOICE FOR SYMPTOM DROWSINESS. GROUP CP-CC-II (N = 24). THE DASHED LINE IS THE CP MATCHING LINE.	58
22. EXPECTED NUMBER OF ERRORS AS A FUNCTION OF π_0 FOR THREE DIFFERENT STRATEGIES	64

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CHAPTER I

INTRODUCTION

During the past ten years there has been an increasing research interest in decision behavior in binary choice situations. Most of the experimental studies have been restricted to cases in which the same stimulus is presented on each trial. However, there have been a few studies in which the same stimulus is not presented on each trial. Burke and Estes (1957) proposed a model for the latter type of situation which has been called probabilistic discrimination learning. Since 1957 there have been very few studies relating to probabilistic discrimination learning, and, in general the results of such experiments have not been in agreement with the Burke-Estes model. (See, for example, Atkinson, Bogartz, and Turner, 1959; Shaffer, 1962.)

More recently, interest has developed in Bayesian models of decision making. Shuford and Hall (1959) presented a Bayesian interpretation of psychophysical judgments and suggested an asymptotic response model for judgment behavior in a percentage estimation task. Later, Wiesen and Shuford (1962) tested this model in an experiment in which Ss were shown the central nine elements of 16x16 matrices composed of randomly placed 1's and 0's. The task was to estimate the proportion of 1's in the large 16x16 matrices from observing the samples of size nine. In this case S was permitted to use any of the 101 response alternatives 0%, 1%, . . . , 100%. If this task is changed so that S is only permitted to use

two response alternatives, say, A_0 and A_1 , the decision task is formally identical to the probabilistic discrimination learning task.

The relation between the two tasks prompts appropriate consideration of the possible role of a Bayesian model of decision making in a learning task. This role will be clarified in a moment, but it is first necessary to give a more explicit statement of the type of task under consideration.

Each trial of an experiment is initiated by the onset of an unambiguous stimulus such as a colored light (Shaffer, 1962). The trial is terminated when, after S has made his choice, the experimenter announces the choice which is correct for the trial. Let S denote the exhaustive set of mutually exclusive stimuli, $S = \{s_1, s_2, \dots, s_n\}$. Let E_0 and E_1 denote the two possible events and let A_0 and A_1 denote the two responses available to S . Further let $P_k(E_j | s_i)$ denote the proportion to times that event E_j has been called correct for stimulus s_i up to, but not including the k^{th} trial.

The stimulus to be presented on a given trial is chosen by the following scheme. Let π_0 be the probability that event E_0 occurs on a given trial. A Bernoulli process is used to generate a sequence of events of type E_0 and E_1 . Further let $P'(s_i | E_j)$ denote the probability that stimulus s_i will occur on a particular trial given that E_j is the event for that trial. A random process is used to generate the stimuli in conformity with the probability measure $P'(s_i | E_j) = P_{ij}$. (Investigators may not always use this scheme to generate the stimulus-response assignments. Rather, that is one way to do it, and conceptualizing the process in

this way leads to a clear picture of the structure of the experimental task as objectively defined.)

It will be recalled that Bayes theorem may be written $P(B_1|A) = P(B_1)P(A|B_1) / \sum_{i=1}^n P(B_i)P(A|B_i)$

if B_1, B_2, \dots, B_n are mutually exclusive, and if $A \subset B_1 \cup B_2 \cup \dots \cup B_n$. From this it follows that

$$(1) P'(E_0|s_1) = \pi_0 P'(s_1|E_0) / [\pi_0 P'(s_1|E_0) + (1 - \pi_0) P'(s_1|E_1)]$$

where $P'(E_0|s_1)$ is the objective posterior probability of event E_0 given stimulus s_1 . A similar expression can be written for $P'(E_1|s_1)$.

On each trial, then, S is presented with an unambiguous stimulus and is to guess or decide which event will follow. As the trials proceed S is able to obtain a more accurate estimate of the posterior probabilities, $P'(E_j|s_1)$ since S is told which event occurred on each trial after he has made his choice. At the moment that S makes a choice, he will never be certain that his choice is correct, but he can maximize the expected number of correct choices for each stimulus by choosing that alternative which has more often been associated with the stimulus in the past.

The task described above can clearly be interpreted as one of decision making under uncertainty. On each trial S is to make a decision about the state of the world (it is either E_0 or E_1) in the light of certain information relating to that state (this stimulus has been associated with E_0 more often in the past than with E_1). There are certain advantages to be expected from viewing this task within a decision-theoretic frame of reference. For one thing, it will clearly show how choice behavior directed toward

achieving maximum expected payoff is effected by certain structural changes to be introduced. The result of the decision-theoretic analysis will provide a reference point which will help in interpreting the choice behavior of subjects performing the task. It should not be used to convince or dissuade one that individuals are "rational" or "irrational," rather it should be viewed as an aid in understanding choice behavior. [The discussion section of this dissertation will be evidence of the heuristic value of a decision-theoretic approach.

In order that the relation between learning and decision making be clarified, it will be helpful to distinguish two levels of organization which lead to changes in response behavior as a function of trials. The first level of organization is concerned with the utilization of a particular decision rule. For instance, consider the decision rule which maximizes the number of correct choices over the trials of the experiment.

- (2) Choose A_0 for s_1 whenever $\delta_{1k} > 1/2$.
 Choose A_1 for s_1 whenever $\delta_{1k} < 1/2$.
 Choose A_0 with probability $1/2$ and A_1 with probability $1/2$ for s_1 whenever $\delta_{1k} = 1/2$,

where $\delta_{1k} = P_k(E_0 | s_1)$. In order that this rule be applicable throughout an experiment, it is necessary to define δ_{11} . One way to do this is to assume that δ_{11} is the mean of an uncertainty distribution of $P'(E_0 | s_1)$, and that this distribution can be represented by a beta distribution with parameters $(r' = 1, n' = 2)$. The mean of this distribution is $\delta_{11} = \frac{r'}{n'}$. After the k^{th} trial

$$(3) \quad \delta_{1k} = \frac{r' + (\text{Number of times } s_1 \text{ has been followed by } E_0)}{n' + (\text{Number of times } s_1 \text{ has occurred})}$$

(See Appendix I for a more detailed explanation of this decision rule.)

As mentioned before this decision rule will maximize the number of correct choices over the trials of the experiment. The stimuli represent the inputs to the decision rule, and the responses represent the outputs. Because of the nature of the task, the output for a particular input will change as a function of trials. (Note that this is not necessarily the case, but will be true as $P_k(E_0|s_1)$ fluctuates about one-half.) The processes which lead to response changes relative to a specific decision rule are ones of assimilation and utilization of information. To the extent that different individuals use different decision rules, the use of response proportions obtained from groups of subjects and averaged over trials will yield little information concerning these processes.

Assume that a person uses the decision rule in expression (2) in this situation. Are there instances in which his responses would not be predicted by the output of the decision rule? Obviously, the first time a stimulus occurs, and whenever else $P_k(E_0|s_1)$ is equal to one-half, the decision rule does not specify a unique response. But besides these cases, perfect use of the decision rule requires that there be errorless identification of the stimuli and correct choices, and that memory be perfect. Assuming that sufficient allowances are made by the experimenter to eliminate errors due to memory or misidentification, the output of the decision rule will predict S's responses in all cases except where $P_k(E_0|s_1)$ is equal to one-half. If the decision rule used by S is not known to the experimenter, response

changes are liable to be attributed to some other process.

The other level of organization to be distinguished here is that which relates to changes of the decision rule in an experiment. The experimenter knows how the stimulus-event assignments came about, and is, therefore, able to specify the decision rule which will be best for achieving some performance criterion. If, for instance, the experimenter knows that a regular sequence is being used such as "stimulus s_1 is followed by E_0 three times, by E_1 twice, by E_0 three times, by E_1 twice, etc.," the decision rule given in (2) would not be the best for achieving the maximum expected number of correct choices. It is only in terms of the experimental structure specified earlier that the decision rule given in (2) is best. The individual performing the task is very likely not to perceive the situation as it actually is structured. Even if the experimenter goes to some length to explain the structure to S , there may be some lack of understanding or some feeling that there is a solution which will improve performance. This is not an attempt to explain deviations from the optimal rule in terms of mistrust or stupidity on the part of S , but it must be accepted that the experimenter has less than complete control over S 's perception of the task.

The effect of this difference in perception is that S may adopt different decision rules at different stages in the experiment, or he may adopt one decision rule, but this rule may not be the best rule for achieving the goals set by the experimenter, considering the structure of the task as known by the experimenter. Again, use of response proportions obtained from trial by subject averaging would seem to yield

little information concerning what decision rules are adopted by the individuals who comprise a group, and would defy analysis of the effect which experience with a particular task may have upon the change of decision rule.

There are those who would argue that this method of attacking the problem has little merit (see Estes, 1962). Yet it would seem instructive to see what kinds of questions arise once this approach has been adopted. One area of interest is concerned with identifying the decision rules which are adopted by S in this type of situation. Toda (1962) has conducted several experiments to investigate the kinds of decision rules which are adopted by subjects in a probability learning task. One of his most interesting findings is that the proportion of deterministic hypotheses is greater than the proportion of stochastic hypotheses during the early trials of the experiments. In one experiment consisting of 100 trials, the proportion of stochastic hypotheses became greater than the proportion of deterministic hypotheses only after 40 trials. In this case, no advance information was given concerning the nature of the event sequence. (Those who are doubtful about the relationship between rules stated by subjects and the resultant behavior are referred to a very interesting account of the interpretation of rule statement given by Verplanck, 1962. Although the task in Verplanck's experiment was a concept identification task, he makes a penetrating analysis of the relation between rule statement and choice behavior. Similar evidence for correspondence between verbal rule statement and subject's performance on a task is to be found in the recent dissertation of Johnson, 1961.)

Another type of question arising from this approach relates to the structure of the task as presented to S. As mentioned before, the specification or adoption of a decision rule depends upon understanding the structure of the task as well as the performance criterion which is adopted. Experiments have been conducted in probability learning situations in which the instructions given to S at the beginning of the experiment have been varied in one manner or another. For instance, Nies (1962) gave one group of Ss the usual probability learning instructions. Another group was told that the events tended to occur in definite patterns. A third and fourth group were told the ratio of E_0 to E_1 , with the fourth group receiving additional information that there could be no fixed pattern. (E_0 occurs more frequently than E_1 in all cases.) In all these cases the events consisted of outcomes when drawing marbles from a box with replacement. A control group was added with the usual probability learning instructions, but the box was missing. (The intended effect of the box for groups 1-4 was to suggest randomness.) The finding was that the information supplied to Ss led to differences in performance during the first 150 trials. The groups who were told the ratio of E_0 to E_1 gave more A_0 responses during these early trials. Furthermore, while the control group probability matched, that is, the asymptotic probability of A_0 approached π_0 , during trials 201-250, the other groups gave significantly more E_0 guesses. This study, and others (for instance, McCracken, Osterhout and Voss, 1962) are related to the structure of the task as presented to S. The major deficiency is that there is no way to state exactly what changes in behavior are to be expected as a result of varying the

instructions given to S. However, there are other ways to manipulate the structure of the task as presented to S which lead to an exact formulation of the differences which are induced in the logical structure of the task. Knowing what effect a change in structure should have in terms of the logical properties of the task will afford a baseline with which to compare the performance of Ss in the experiment.

CHAPTER II

DESIGN OF EXPERIMENT

One purpose of this dissertation is to present a decision-theoretic analysis of certain choice situations which arise when certain aspects of the probabilistic discrimination learning situation are changed. One aspect to be considered is the relationship among the stimuli in these choice situations, while the other aspect is the information concerning which event occurred on each trial. These changes affect the logical structure of the situation and, presumably, the perceived structure. The other purpose of this dissertation is to investigate and interpret the choice behavior of subjects in the different situations.

Before the exact nature of the proposed changes is presented, it is necessary to set the boundary conditions. The performance criterion to be used is that of maximizing expected payoff. In order to simplify the discussion, a payoff matrix which can be reduced to the following form will be used:

	E_0	E_1
A_0	u	0
A_1	0	u

In this matrix E_0 and E_1 are the two possible events, A_0 and A_1 are the response alternatives, and each entry in the matrix is the payoff realized if response A_j is chosen and event E_j occurs. (See Appendix I for a discussion of matrices which, for the purposes here, can be reduced to this form.)

The purpose, then, of what follows is to show the effect that certain structural changes will have on the choices of a person who behaves so as to maximize expected payoff.* This person must be capable of correctly identifying the stimuli and of recognizing correct responses after being given identification of the occurring event. He must also be able to remember certain things about the sequence of events.

Three different experimental settings will be discussed. The first is identical to the probabilistic discrimination learning situation discussed earlier. The second is similar to this with one major exception--that the conditional probabilities, the $P'(s_i|E_j)$, are given at the beginning of the experiment. The third setting resembles the second in that the conditional probabilities are given, but differs in that in the second setting S is told which event occurred after he has made his choice, while in the third setting S is not given this information. These settings will be discussed one at a time, and the manner in which the output of the decision rule changes as a function of trials will be shown.

Task CC.--In this case S is given the correct choices on each trial, but there is no a priori relationship among the stimuli. The decision rule which maximizes expected payoff is given in expression (2). Use of this decision rule requires that the quantity $P_k(E_0|s_i)$ be remembered for each stimulus. As the number of stimuli increases, so does the number of different quantities which must be remembered. Before a particular stimulus has occurred, there is no logically compelling reason to favor one response over the other.

*The term optimal choice will be used to denote that choice which has the higher objective expected payoff given that all conditions and parameters relevant to the choice are known.

For instance, assume that stimulus s_1 occurs for the first time on trial 20, that the correct choice for all previous trials has been E_0 , and that several other stimuli have occurred. One assumption which would lead to favoring E_1 on trial 20 is that there must be some stimulus which is an indicator of E_1 . Since, to this point, other stimuli have indicated E_0 , it is more likely that E_1 is correct for s_1 , the stimulus presented on trial 20. On the other hand, one might assume that since all of the stimuli up to trial 20 have been associated with E_0 , it is more likely that the stimulus presented on Trial 20 also indicated E_0 . Neither argument can be defended without adding assumptions other than those known to be true from the way in which the task is presented. However, setting δ_{11} equal to one-half requires no extra assumptions.

Task CP-CC.--For the task described above, then, there is no a priori relation among the members of the stimulus set. However, if the conditional probabilities are given at the beginning of the experiment, there is a definite relation among the stimuli.

As shown in Appendix I, the decision rule which maximizes expected payoff for this condition is very similar to the decision rule presented in expression (2) for the CC condition. The decision rule is

- (3) Choose A_0 for s_1 whenever $P_\ell(E_0|s_1) > 1/2$.
Choose A_1 otherwise.

In expression (3) $P_\ell(E_0|s_1)$ is the posterior probability of E_0 given stimulus s_1 . The posterior probability is a function of the conditional probabilities relevant to the stimulus s_1 , the sequence of events up to, but not including, the ℓ^{th} trial,

and an initial prior distribution. The role of the latter distribution will be clarified in a moment. Decomposition of the terms in expression (3) into prior and conditional probabilities leads to some interesting facts. Consider, for instance, $P_\ell(E_0|s_1)$.

$$(4) \quad P_\ell(E_0|s_1) = P'(s_1|E_0)\bar{\pi}_\ell / [P'(s_1|E_0)\bar{\pi}_\ell + P'(s_1|E_1)(1-\bar{\pi}_\ell)].$$

Every quantity in this equation is familiar with the exception of $\bar{\pi}_\ell$. If the proportion of E_0 events is known, $\bar{\pi}_\ell = \pi_0$. When the proportion of E_0 events is not known, $\bar{\pi}_\ell$ is the mean of a distribution. This distribution reflects the uncertainty about the proportion of E_0 events. Assume that at the beginning of an experiment S feels that the proportion of E_0 events is equal to the proportion of E_1 events, but it would take very little information for him to be convinced otherwise. That is, S is uncertain about the true proportion of E_0 events, and he places little faith in any one number. This subjective distribution can be approximated by a beta distribution with parameters ($\alpha = 1, \beta = 1$), the uniform distribution of the interval (0,1). This distribution is changed as a function of trials, and it is the mean of this distribution which is relevant in making decisions. Decision rule (3) can be re-written

$$(5) \quad \text{Choose } A_0 \text{ whenever } P_\ell(E_0|s_1) / P_\ell(E_1|s_1) > 1.$$

Choose A_1 otherwise.

Substituting the term on the right side of (1) for the terms on the left side of (5) and rearranging terms, (5) becomes

$$(6) \quad \text{Choose } A_0 \text{ whenever } \bar{\pi}_\ell > \frac{P'(s_1|E_1)}{P'(s_1|E_0) + P'(s_1|E_1)}.$$

Choose A_1 otherwise.

The right side of (6) is fixed by the initial conditions of the experiment. It is the value of $\bar{\pi}_\ell$ which determines the choice on each trial. The distribution of π_ℓ is given in Appendix I. A proof that $\bar{\pi}_\ell$ converges to π_0 is also given.

The essential aspects are that the distribution of π_ℓ depends only upon the number of times that E_0 has occurred up to the ℓ^{th} trial. There is only one quantity which needs to be remembered, and the information about the correct choices for all stimuli is logically relevant to the choice to be made for any one stimulus. In general, performance, as determined by reference to the optimal choices, is better when the conditional probabilities are given than when these probabilities are not given. The optimal choice is the choice which has the higher objective expected payoff.

Task CP-CC.--The third experimental setting is similar to the second with the exception that the correct choices are not given on each trial. In this case the decision rule given in equation (6) is also applicable. The difference in this situation is the distribution of π_ℓ . In this case, the distribution depends upon the ratio $P'(s_1|E_0)/P'(s_1|E_1)$. The result that the decision rule is the same for the CP-CC condition and the CP- $\bar{C}\bar{C}$ condition and that the only difference between these two conditions is the distribution of π_ℓ is rather surprising. The essential aspect here is that with the CP-CC condition the result of each trial is the exact knowledge of which event occurred, while with the CP- $\bar{C}\bar{C}$ condition each trial terminates with information concerning the likelihood that the stimulus for that trial was produced by either of the events. This is to some extent similar to making inferences about a parameter on the basis

of an infinite sample (CP-CC) as opposed to a small sample (CP-CC). The reader is again referred to Appendix I for the details. In this case, $\bar{\Pi}_k$ does not converge to Π_0 as rapidly as when the correct choices are given. Performance in this case should be worse than in the other two cases.

The experiment to be reported here was designed to compare the performance of Ss in these three conditions. The first purpose is to see how far the performance of Ss in each setting diverges from the respective optimal performance. The second purpose is to see how performance of Ss in each group compares with performance of Ss in the other groups.

It is not to be expected that actual performance matches the performance of the optimal models. The optimal models entertain no false hypotheses about the structure of the situation, have perfect memory, and compute solutions from analytic equations. The optimal models use an unambiguous and inalterable performance criterion. On the other hand, humans do not have perfect memory, may adopt one of an infinite variety of performance criteria, and are quite likely to entertain false pattern hypotheses.

The main value of the optimal models is that they show exactly what differences are induced in choice behavior by the changes which are made. They afford a standard against which the performance of Ss can be compared, and hence give more meaning to differences in performance by Ss in the different settings.

It is expected that some Ss in the condition where the conditional probabilities are not given, but the correct choices are given (CC) will adopt a decision rule similar to,

if not identical to, that presented in (2). The performance of this group should be somewhat nearer the optimal performance than a probability matching performance. This result would be consistent with the findings by Estes, Burke, Atkinson and Frankmann (1957).

Where the performance of the Ss who receive both conditional probabilities and correct choices (CP-CC) will stand relative to the model performance and relative to the performance of the (CC) group is an open question. Shuford and Wiesen (1959) have offered evidence for a Bayesian interpretation of proportion estimates in the experiment mentioned earlier. In this case it is difficult to tell whether the Ss are learning the posterior probabilities, or whether there is some perceptual reorganization related to the distribution of stimuli being used. Ward Edwards (personal communication) has conducted some experiments in which the task was to estimate posterior probabilities from information about the conditional probabilities and the prior probabilities. The Ss performing this task do not make very accurate use of the information and their estimates are not very well related to the objective posterior probabilities. The experimental task to be used here is somewhere between these two tasks. It differs from the Edwards experiment in that the task is to make a choice and not an estimate. However, in order to make his choice in agreement with the optimal model, S must be able to integrate information about the prior probability with information about the conditional probabilities. This is what the Ss in Edwards' experiment were not able to do very well at the level of stating estimates of the posterior probabilities.

Behaviorally, then, the task under consideration here is more similar to the task presented by Shuford and Wiesen in that S must make a decision rather than an estimate of a posterior probability. However, the point of focus in the Shuford-Weisen experiment was the asymptotic responses of the Ss. As mentioned before, there is a possibility that the posterior probabilities were being learned. However, in the task under consideration here, the point of focus is the trial by trial changes in choice behavior. It should be rather easy to discriminate learning of posterior probabilities from a process which combines the information about the prior probabilities and the information about the conditional probabilities. It will not be surprising if the performance of Ss in the (CP-CC) condition is rather similar to the performance of those in the (CC) condition.

The performance of Ss in the condition where the conditional probabilities are given, but no correct choices are given (CP- \overline{CC}) should not be as good as the performance of the other groups. However, the difference between the Ss' performance and the performance of the model might be greater in this condition than in the others. Wiesen and Shuford (1962) used this condition in the matrix experiment discussed earlier, and found, essentially, no change in performance as a function of trials. Most Ss tended to respond with estimates near the proportion given in the sample matrix. In the case of the experiment being performed here, the main difference between the two groups (CP-CC) and (CP- \overline{CC}) is the information given to the Ss concerning the proportion of E_0 events. The Ss in the latter group must get this information from the stimuli which occur, while

the Ss in the (CP-CC) group are told which event occurs on each trial. However, the extent to which Ss are incapable of using this information should increase the difference between these two groups. The Ss given the correct choices can learn the posterior probabilities, while Ss who are not given the correct choices have no recourse but to use the information about the proportion of E_0 events if they wish to improve performance over that attainable by responding on the basis of the conditional probabilities. For some stimuli the conditional probability of the stimulus given E_0 is greater than the conditional probability of the stimulus given E_1 . The reverse is true for other stimuli. An S who always chooses his response according to which event produces the greater conditional probability is responding on the basis of the conditional probabilities.

CHAPTER III

EXPERIMENTAL METHOD

The Task.--The Ss were given a brief explanation of the problem confronted by a physician who must recommend treatment for an ailment when he is not sure exactly what the ailment is. The following situation was then described to the Ss: The result of a blood analysis shows that each of a group patients has one and only one of two possible strains of a certain virus. However, exactly which strain each patient has is not known since the blood test cannot discriminate between the two strains. The two strains are labeled virus Y and virus O. When a patient is presented for diagnosis he reports a symptom, and the task is to prescribe the appropriate treatment for the patient. There is one drug which is effective in curing a patient who has virus Y, and another drug which is effective in curing a patient who has virus O. Since the drugs interact in a potentially harmful way, both drugs cannot be administered to a single individual. The possible symptoms which a patient may report are: Headache, Sore Throat, Nausea, Fever, Drowsiness, or Backache. (The complete instructions for each group appear in Appendix II.)

Subjects.--The Ss were 163 volunteer undergraduate students from an introductory psychology course. The ratio of male to female was about six-to-one. The Ss were run in six groups, each group corresponding to one of the three experimental settings with E_0 defined as virus Y for roughly

half of each condition, and E_0 defined as virus 0 for the other half. The S_s were randomly assigned to conditions with the constraint that some S_s were free to schedule experimental meetings only at one particular time. This latter condition characterized about 25 S_s who were approximately equally distributed among the six groups. Originally there were 30 S_s scheduled for each group, but some S_s failed to keep the appointment. It was decided that the utility of having equal numbers in each group was overshadowed by the disutility of finding more S_s and running these S_s in small groups of two or three. The number of S_s in each group was as follows: CC-O, 25; CC-Y, 23; CP-CC-O, 30; CP-CC-Y, 27; CP- $\bar{C}\bar{C}$ -O, 29; CP- $\bar{C}\bar{C}$ -Y, 28. (One S was discarded from group CC-Y because he used the stimulus-free strategy of systematically writing down 10 A_0 responses, 10 A_1 responses, etc.)

Stimulus-Correct Choice Series.--A Bernoulli process was simulated on an LGP-30 computer to generate the sequence of events using the multiplicative congruential method (Tausky and Todd, 1956). The probability that E_0 occurs on a given trial, π_0 , was .80. In order to generate the stimuli, the conditional probabilities were obtained by using two binomial processes with ($n = 5$) and letting the number of successes each represent a symptom. That is, no successes was substituted for a headache, one success for sore throat, . . . , and five successes for a backache. When E_0 was the event for a given trial, the binomial process had a parameter ($p = .65$), while with E_1 ($p = .40$). The same process as described above was used to generate the values of r , the number of successes in a sample of size five. The theoretical condition, marginal and posterior probabilities, and the marginal and pos-

terior probabilities obtained from the sequence which was used in all conditions are given in Table 1. The equation for the marginal probabilities, $f(r|\pi_0)$, is

$$f(r|\pi_0) = \pi_0 f(r|n, p_0) + (1 - \pi_0) f(r|n, p_1).$$

The posterior probabilities are obtained from equation (7)

$$(7) \quad f(p_0|r) = \pi_0 f(n|p_0) / [\pi_0 f(r|p_0) + (1 - \pi_0) f(r|p_1)].$$

TABLE 1

THEORETICAL CONDITIONAL, MARGINAL, AND POSTERIOR PROBABILITIES, AND OBSERVED MARGINAL PROBABILITIES

$$\pi_0 = .80, p_0 = .65, p_1 = .40, n = 5$$

r	$f(r p_0)$	$f(r p_1)$	$f(r \pi_0)$	Observed	$f(p_0 r)$	Observed
0	.005	.078	.020	.053	.213	.250
1	.049	.259	.091	.100	.430	.467
2	.181	.346	.214	.200	.677	.700
3	.336	.230	.315	.287	.854	.907
4	.312	.077	.265	.267	.942	.951
5	.116	.010	.095	.093	.973	1.000

Procedure.--The name of each symptom was printed with black ink in 1 1/2" high letters on a 9" high by 20" wide white card. These cards were hung along the top of the blackboard at the beginning of the experiment and remained there throughout the experiment. The name of each of the strains of virus was printed in 1 1/2" high letters on a 5" high by 12" wide card. The color was black for the CC groups, and one name was in blue and one in red for the CP-CC

and CP- \overline{CC} groups. The reason for this will be explained in a moment. These cards were hung, one above the other, on a stand in front of the experimenter.

Each S was given an answer booklet and a pencil. The answer booklet was composed of four pages each of which had space for recording the first letter of the symptom presented on the trial, a space for S to record his choice, and a space to record the correct choice. The space for recording the correct choice was omitted from the answer sheets for the CP- \overline{CC} groups.

The basic nature of the task was explained to all Ss. The Ss were told that if the strain of virus which a patient had was correctly identified, the patient would recover in a few hours, but if the strain was not correctly identified, the patient would not recover for a few days. The Ss were told that they could not be correct in every case, but it was important to try to be right as often as possible.

The Ss in the CC groups were simply told:

As the experiment proceeds you may see that Virus O is associated with some symptoms more often than is Virus Y. On the other hand, you may see that Virus Y is associated with other symptoms more often than is Virus O. Your task is to make a choice on each trial, and to try to be correct as often as you can.

After the general instructions were read to the Ss in the CP-CC and CP- \overline{CC} groups, a figure which contained the conditional probabilities on a 12" high by 18" wide white card was hung at the top-center of the blackboard. The symptoms which had greater conditional probabilities for E_0 were to the right of the figure, while the other symptoms were to the left of the figure. The order of the symptom cards from left

to right was in agreement with the order in which the symptoms appeared on the figure. This order corresponded to the numerical ordering on r. (The order of symptoms from left to right for the CC groups was a random order of this configuration.) The figure contained the first letter of each symptom. Above each letter there were two half-inch wide rectangles, one blue and one red. The height of the blue rectangle was proportional to the conditional probability of that symptom given that the patient had the strain of virus designated as E_0 , while the height of the red rectangle was proportional to the conditional probability of that symptom given that the patient had the virus designated as E_1 . The constant of proportionality was approximately $1'' = .05$. The role of E_0 and E_1 was reversed by having the word "Virus Y" in blue for one group, and in red for the other group.

The Ss were told that the records of a thousand patients who were known to have virus Y and of a thousand patients who were known to have virus Q had been obtained. The figure represented the number of patients with each virus who reported each symptom. It was pointed out that it might have been more difficult to obtain the thousand records for the one strain than for the other since it might be that there are more people with the one strain than the other. The Ss were told that even though a particular symptom may occur more frequently when one strain is known to be present than when the other strain is known to be present, it does not follow that presence of the symptom would more likely indicate the first strain. The Ss were told that they should consider the overall frequency of each strain in making their choices. The Ss in the CP-CC group were told that they would get an

idea of these frequencies since the correct choice would be given after they had made their choices. The Ss in the CP- $\bar{C}\bar{C}$ groups were told that they would get an idea of these frequencies by paying attention to which symptoms tended to occur more frequently. If symptoms favoring E_0 tended to occur more frequently than symptoms favoring E_1 , it would indicate that E_0 was occurring more frequently than was E_1 , and vice versa. The only question came from the (CP- $\bar{C}\bar{C}$) groups. There was some protest that the task was not possible, but the experimenter tried to clarify the task by rephrasing the instructions.

Each trial consisted of the following steps:

- 1.) The experimenter announced the trial number, took the top card from a pre-arranged pack, read the name of the symptom appearing on the card, and pointed to the appropriate symptom card at the top of the blackboard.
- 2.) The S recorded the first letter of the symptom and his choice.
- 3.) Fifteen seconds after the initiation of step 1.), the experimenter read the name of the correct virus and pointed to the appropriate card containing the virus strain.
- 4.) The S recorded the correct strain on his answer sheet.
- 5.) Five seconds after the initiation of step 3.), the next trial was announced.

For the CP- $\bar{C}\bar{C}$ groups, steps 3.), 4.), and 5.) were omitted and there was a fifteen second inter-trial interval. A stop watch was used to time the intervals in all cases.

Six practice trials were given. Each symptom was presented once during the practice trials, but no correct choices were given. The experimenter merely indicated, where appropriate, how this would be done during the experiment.

At the termination of the 150 trials, each S was asked to write a brief paragraph or so in response to the following questions.

1.) What approach did you use in making your decisions?

2.) If you were to perform the same task again, do you think that you would do anything differently? If so, what?

When the Ss had finished answering the above questions, a short questionnaire was passed out. The general purpose of the questionnaire was to try to get some further information relating to questions 1.) and 2.) above. The specific content of the questionnaire differed slightly from one group to the next, but the general content was the same.

CHAPTER IV

RESULTS

The Results to be presented here are composed of two related, but different, translations of the data. The first translation is in the form of cumulative regret functions. A cumulative regret function is obtained as follows: Assume that the payoff for a correct choice is one unit, while the payoff for an incorrect choice is zero units. For each symptom there is an optimal choice defined by knowledge of the parameters of the situation. The optimal choice is the choice which has the higher objective expected payoff, and the choice A^* such that

$$E[p(A^*)|s_1] = uP'(E_j|s_1) = P'(E_j|s_1)$$

is greater than or equal to $1/2$. In this expression $uP'(E_j|s_1)$ is the objective expected payoff for choosing A^* . Reference to Table 1 shows that the optimal choice for symptoms H and S is E_1 , while E_0 is the optimal choice for N, F, D and B. The regret for a particular trial is the difference between the objective expected payoff for the optimal choice and the objective expected payoff of the choice actually made by the \underline{S} . If \underline{S} makes the objectively optimal choice, the regret is zero. If \underline{S} does not make the objectively optimal choice, the regret is non-zero, and is small whenever $E[p(A^*)|s_1]$ is near one half, but is large whenever $E[p(A^*)|s_1]$ is near one. In any case, the regret is a function of the choice made by \underline{S} and the objective posterior probability of the event given the stimulus. The regret is

$$(8) \quad g(s_k) = E[p(A^*)|s_1] - E[p(A_j)|s_1]$$

where A_j is the choice made by S . The cumulative regret, $G(s_1)$, is regret summed over trials.

The second translation of the data is in the form of the proportion of S s making the optimal choice for each symptom. This choice is E_1 for H and S, and is E_0 for N, F, D and B.

The cumulative regret function for each group is presented in Fig. 1, together with the regret function obtained from the optimal model for CC and CP-CC conditions. The responses for the two sub-groups of each condition were pooled since there was no systematic difference which could be accounted for in terms of preference for responding either Y or O. The solid line labeled "Model" is the regret function obtained from the optimal model for the CC condition. The dashed line labeled "Model" is the regret function obtained from the optimal model for the CP-CC condition when the parameters of the initial distribution of π are $\alpha = \beta = 25$. The choice, and hence the regret, for this condition depend upon the choice of prior. With these parameters, 95% of the density of the beta prior distribution is between .36 and .64, while 99% of the density is between .32 and .68. This value was chosen for α and β because the optimal model based on this prior distribution generates a regret function which is very similar to the data of some S s. This will be clarified later.

The cumulative regret function labeled "Fig." in Fig. 1 is generated by always choosing that response which has the higher conditional probability as indicated by the figure presented during the experiment. This strategy results in optimal choices in all cases but symptom N. The conditional probability generated by E_1 is greater than the conditional

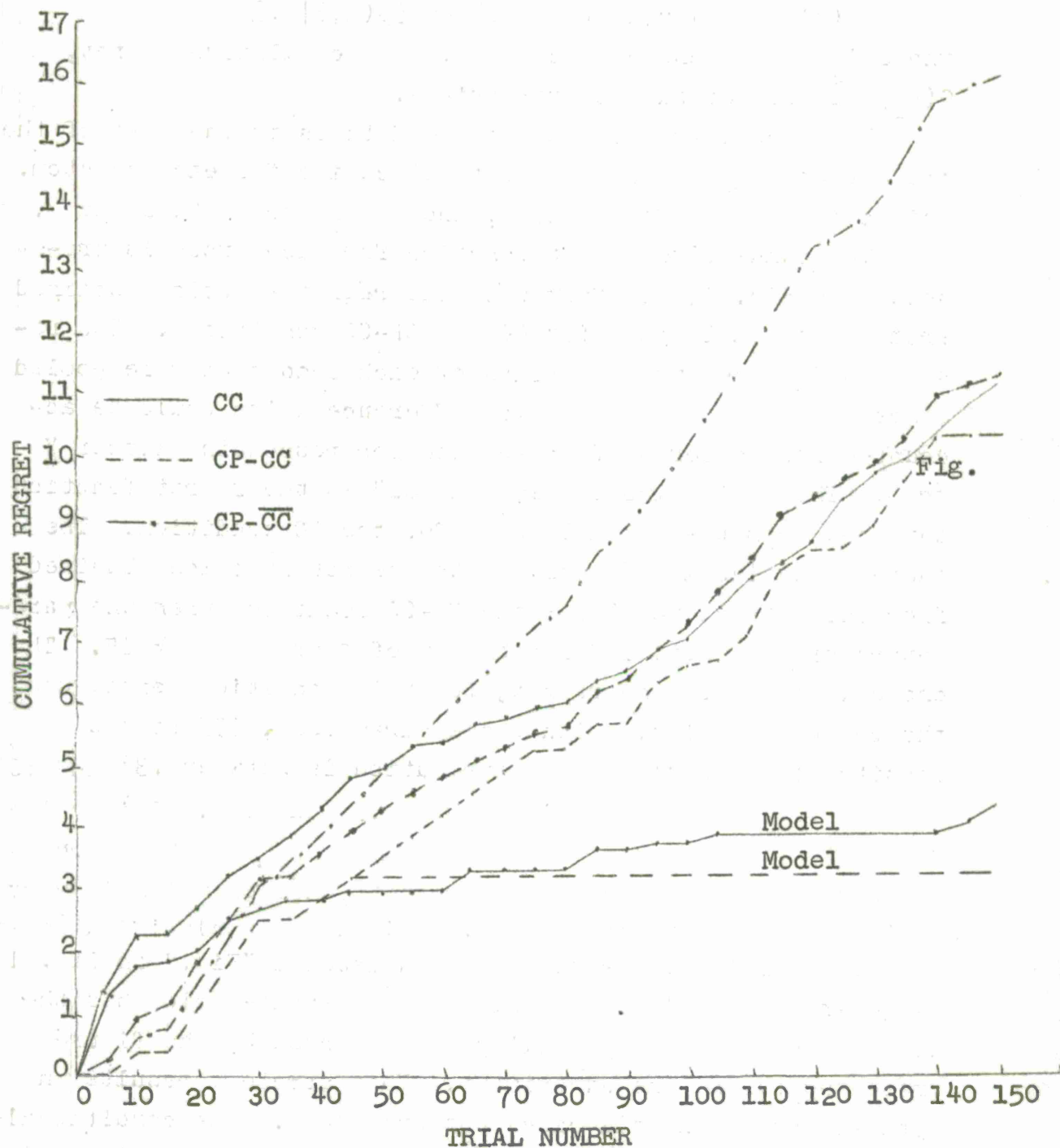


Fig. 1. Cumulative regret function for each group and for optimal model for each condition. Group CC ($n = 48$), Group CP-CC ($N = 57$) and Group CP-CC ($N = 57$).

probability generated by E_0 , but the value of Π_0 is such that the optimal choice is A_0 .

The regret function for the optimal model for the CP- $\bar{C}\bar{C}$ condition is not presented in Fig. 1. Since no simple expression can be found for the mean of the distribution of Π_k for this condition, it was necessary to use a high speed computer to evaluate the mean. Reference to Appendix I shows that the mean of this distribution is the ratio of two polynomials. For $\alpha = \beta = 1$, the polynomial in the numerator is of degree $(k + 2)$, and the polynomial in the denominator is of degree $(k + 1)$. With existing facilities (LGP-30), the computing time required to evaluate this function is tremendous. The mean was computed for the first fifty-four trials, and the model made one non-optimal choice. This was for symptom N on trial 37. The mean of the distribution was well above the critical value necessary to choose A_0 for symptom N, and it is almost certain that the model would make no more non-optimal choices. It would be interesting, but impractical with existing facilities, to compute the mean of this distribution for each trial using the values of α and β which were used for the CP-CC condition, ($\alpha = \beta = 25$). It seems a certainty that the only non-optimal choices which would be made would be for symptom N. This cannot be proved, but an intuitive argument can be given. With $\alpha = \beta = 1$, the mean of the distribution is always above .50 except after trial two, and the mean does not get near the value necessary to choose A_0 for symptom S. This latter value is .842. When $\alpha = \beta = 25$, 95% of the density is between .36 and .64. The effect of this on the mean of the distribution of Π_k will be to keep it closer to .50. That is, it requires more observations to move

the mean up from .50 in this case than when $\alpha = \beta = 1$. Hence there should be more non-optimal choices for symptom N, but this is the only difference to be expected.

During the early trials the empirical functions for Groups CC and CP-CC are very similar to the model functions. For Group CP-CC, this simply means that, during the early trials, both model and subject make their choices in a manner consistent with the response indicated by the conditional probabilities. On the other hand, Ss in Group CC distribute their responses about equally between A_0 and A_1 during the early trials as does the model.

The optimal model for the CP-CC condition makes all optimal choices after trial 42, while the optimal model for the CC condition makes a few non-optimal choices after trial 35. This latter fact is attributable to the sequence of events associated with symptom S. On the other hand, the empirical functions increase beyond these points. The functions for Groups CC and CP-CC are virtually identical, are somewhat S-shaped, and are similar in increase to the "Fig." function. The function for Group CP- \overline{CC} is linear. The performance of the latter group is poorer than that of the other two groups.

There is little more to say about the results in this form. The empirical functions presented in Fig. 1 are averaged over Ss, and it is important to try to assess the contribution of each S to the average. In order to achieve some understanding of this contribution of each S, the cumulative regret function of each individual was inspected. Tables of the individual regret functions evaluated at five-trial intervals are presented in Appendix III. The figures are not presented here because the result of plotting several of

these functions in one figure is utter confusion, and the burden of presenting 162 figures is overwhelming. Inspection of the individual curves for groups CC and CP-CC revealed that the curves could be roughly classified into three categories by looking at the shape of the function between trials 51 and 100, and between trials 101 and 150. There were some curves which were relatively smooth or flat throughout both intervals (FF). Some were smooth between trials 51 and 100 but increased between trials 101 and 150 (FI), while others increased through both intervals (II). About half of the Ss in the CP-CC group made every choice according to which conditional probability was greater as seen on the figure presented to the Ss. The rest of the Ss in this group could be classified as (II), with one exception. This S made two non-optimal choices throughout the experiment. Of the 30 times symptom N occurred, this S made the non-optimal choice in two cases. There were nine Ss in the CP-CC group who made the choice indicated by the conditional probabilities on each trial.

The judgments of flat versus increasing were made by the experimenter by two methods, and by an independent judge using one method. The method used by both judges was visual inspection, while the experimenter also used a numerical method. If the difference in a cumulative regret function was greater than two units between the two limits, either 51-100 or 101-150, the function was considered to be increasing between the limits. Otherwise it was considered to be flat. This arbitrarily chosen value represents a value which is not too far from the increase for the optimal CC model but not too near the increase for the probability matching model.

This categorization rule was violated in two cases in which the result of categorization was an increasing curve between trials 51 and 101 and a flat curve between trials 101 and 150. The amount of increase in the interval 51-100 was only slightly larger than the selected value of two somewhat independent judgments of the experimenter, and the independent judgments of the other rater agreed almost without exception. (If the reader turns to Appendix III, he will see why this is so. The individual differences are by no means small.)

Cumulative regret functions for the three groups with the sub-divisions explained above are presented in Figs. 2, 3, and 4. The curves for various models are also presented. The results of the CC group are presented in Fig. 2. The cumulative regret function for Ss classified as FF ($N = 19$) is identical to the model function in many regions, and overall it is very similar to the model function. There is somewhat more increase in the empirical function between trials 85 and 120 than in the model function. The function for Ss classified as FI ($N = 10$) is everywhere above the function of the FF group, but is very similar up to trial 100. The function for Ss classified as II ($N = 19$) is very similar to the function labeled "Matching" in Fig. 1. The matching function was generated assuming that for each trial δ_{ik} is the probability that S chooses A_0 , while $(1 - \delta_{ik})$ is the probability that S chooses A_1 .

The results of the CP-CC group are presented in Fig. 3. The function for the Ss classified as FF ($N = 12$) is virtually identical to the model curve up to trial 50, but this should be so because the values of the parameters of the prior distribution cannot be made so that there is the observed in-

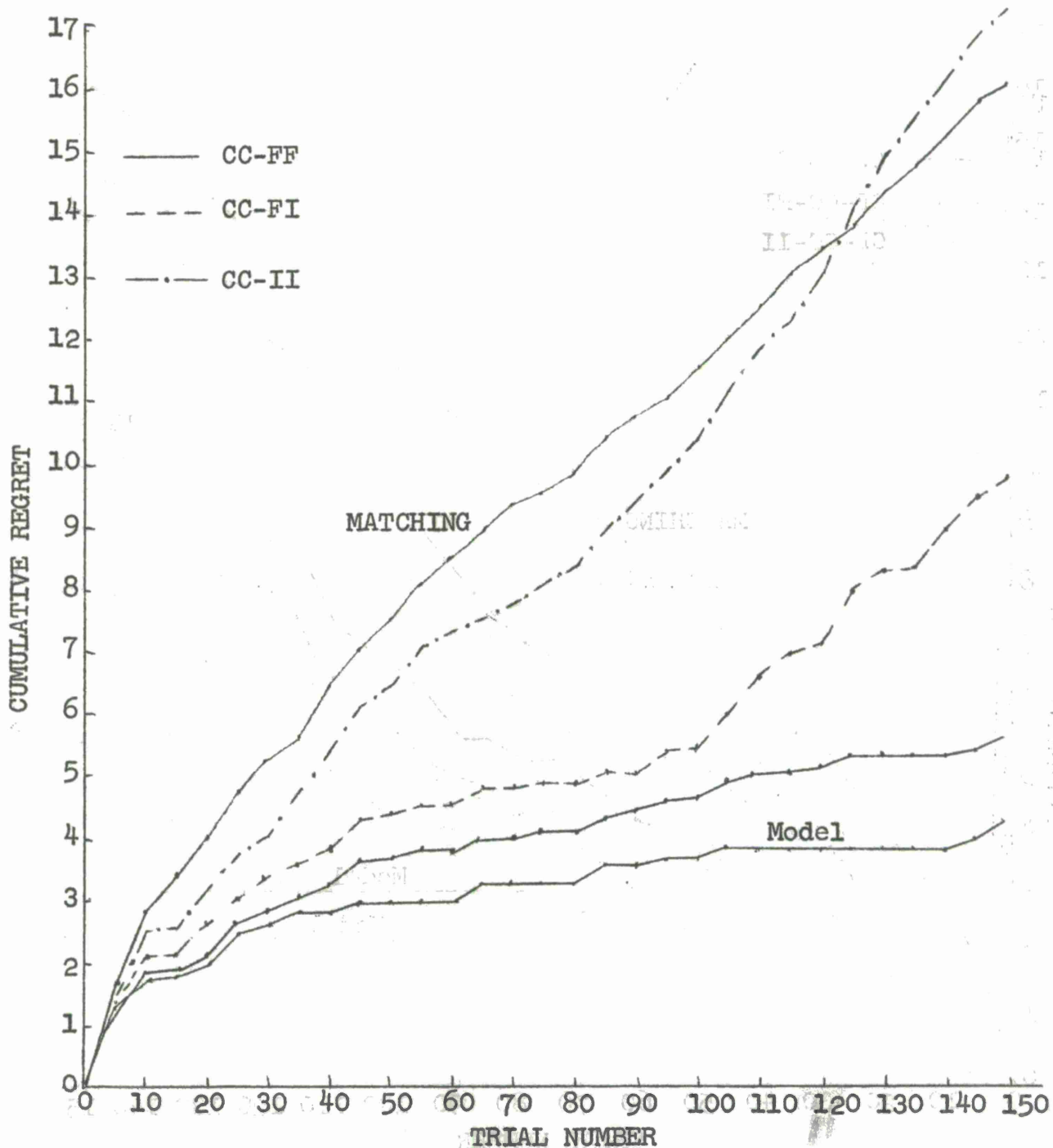


Fig. 2. Cumulative regret functions evaluated at 5-trial intervals for Groups CC-FF ($N = 19$), CC-FI ($N = 10$) and CC-II ($N = 19$). The function labeled "Model" was generated by the optimal model for Group CC.

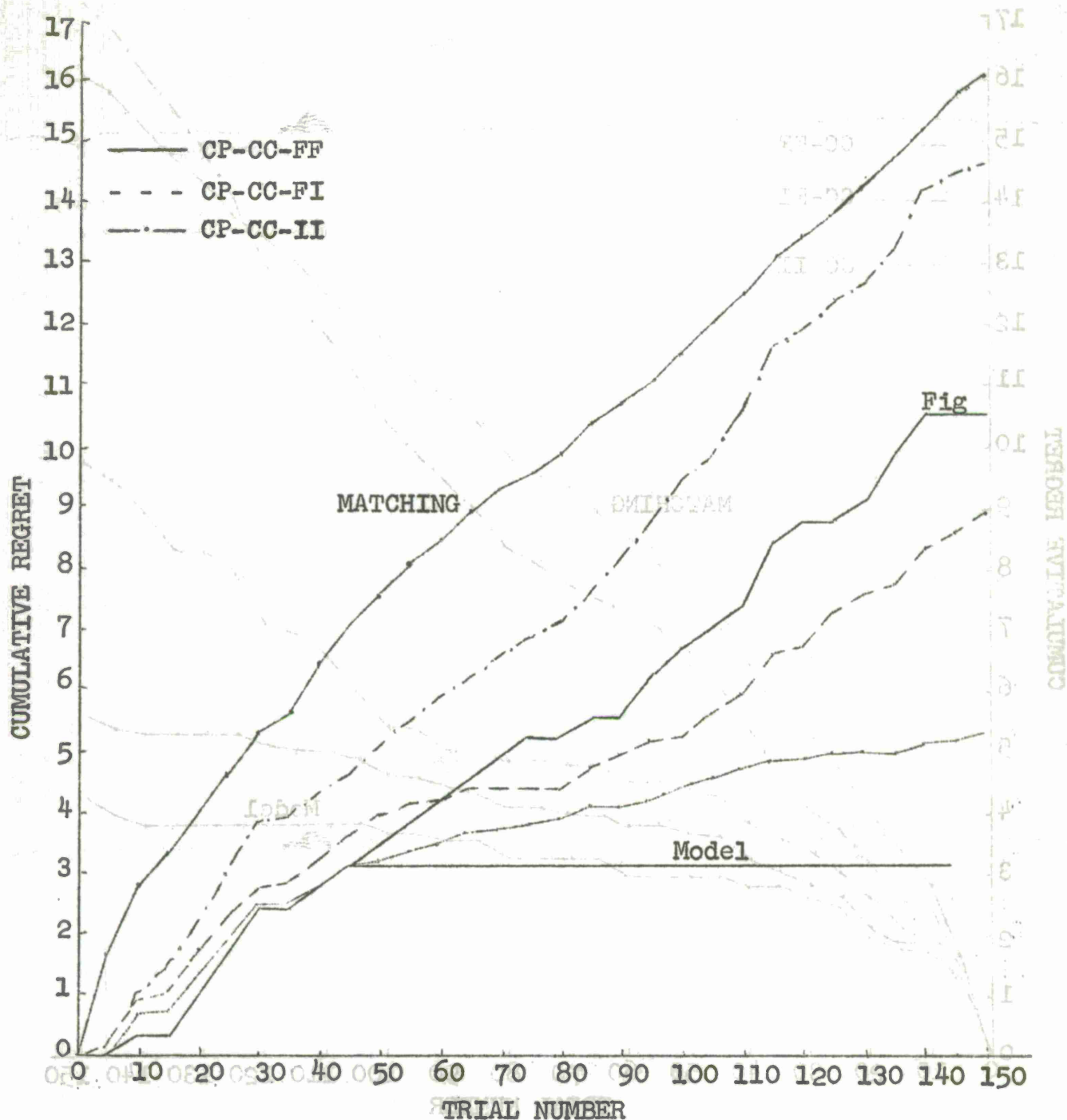


Fig. 3. Cumulative regret function evaluated at 5-trial intervals for Groups CP-CC-FF (N = 12), CP-CC-FI (N = 12), CP-CC-II (N = 23) and CP-CC-Fig. (N = 10). The function labeled "Model" is generated by the optimal model for Group CP-CC with $\alpha = \beta = 25$.

crease during the initial trials and also the observed increase during the last 100 trials. The function of the CP-CC-FF group after trial 50 is more similar to the function generated by the model for the CC condition than the function generated by the model for the CP-CC condition.

The function for Ss classified FI ($N = 12$) is everywhere above the function of Ss classified FF. The two functions are very much the same up to trial 100, but at this point the function of the FI group increases with about the same slope as the matching function. Here again, the function of Ss classified as II ($N = 23$) is similar to the matching function. The function for the other Ss in the CP-CC condition ($N = 10$) is the function labeled "Fig." in Fig. 3. This function is generated by always choosing that response which has the higher conditional probability as indicated by the figure presented during the experiment. This strategy results in optimal choices in all cases but symptom N. In the case of symptom N, E_1 generates the higher conditional probability, but the value of π_0 is such that the optimal choice is A_0 .

The results for the CP-CC group are presented in Fig. 4. (Note the change in scale to accommodate the functions.) The function for Ss who made all choices in agreement with the height of the conditional probabilities ($N = 32$) is again labeled "Fig." It would be interesting to find out what values of α and β (for $\alpha = \beta$) would generate this regret function for the optimal model. Perhaps 25 is not too far from this value. There was one S who made only two non-optimal choices. This S stated that he noticed a preponderance of symptoms for which the conditional probabilities generated by E_0 were greater than the conditional probabili-

ties generated by E_1 , and that he, therefore, decided that the better choice for symptom N was A_0 . This statement is in the intuitive spirit of the model. The other S s ($N=24$) can be classified as II according to the scheme described earlier. The S s in this group follow the figure up to trial 10 only. Beyond this point the empirical function is very similar to a cumulative regret function obtained by a conditional probability matching model (CP Matching). The CP Matching model assumes that for a given trial S chooses A_0 with probability p_1 and chooses A_1 with probability $(1 - p_1)$, where

$$(9) \quad p_1 = \frac{P'(s_1|E_0)}{P'(s_1|E_0) + P'(s_1|E_1)}$$

This model is in the same spirit as a probability matching model when the correct choices are given. The model assumes that S apportions his responses between A_0 and A_1 in agreement with his estimates of the conditional probabilities.

The cumulative regret function for the three sub-groups of the CC and CP-CC conditions are presented in Fig. 5. The functions for the corresponding sub-groups of the two conditions are very similar. The major differences occur during the early trials, and reflect the difference between the conditional probabilities being present or absent. The function for each sub-group of the CP-CC condition is everywhere below its counterpart for the CC condition. The greatest difference is the difference between groups CC-II and CP-CC-II. This is to some degree a function of the classification procedure. A regret function can be flat only if the increase is less than two units between limits, while it can be increasing if the increase is any number greater than two. The range of increases between limits can be checked by reference to Appendix III.

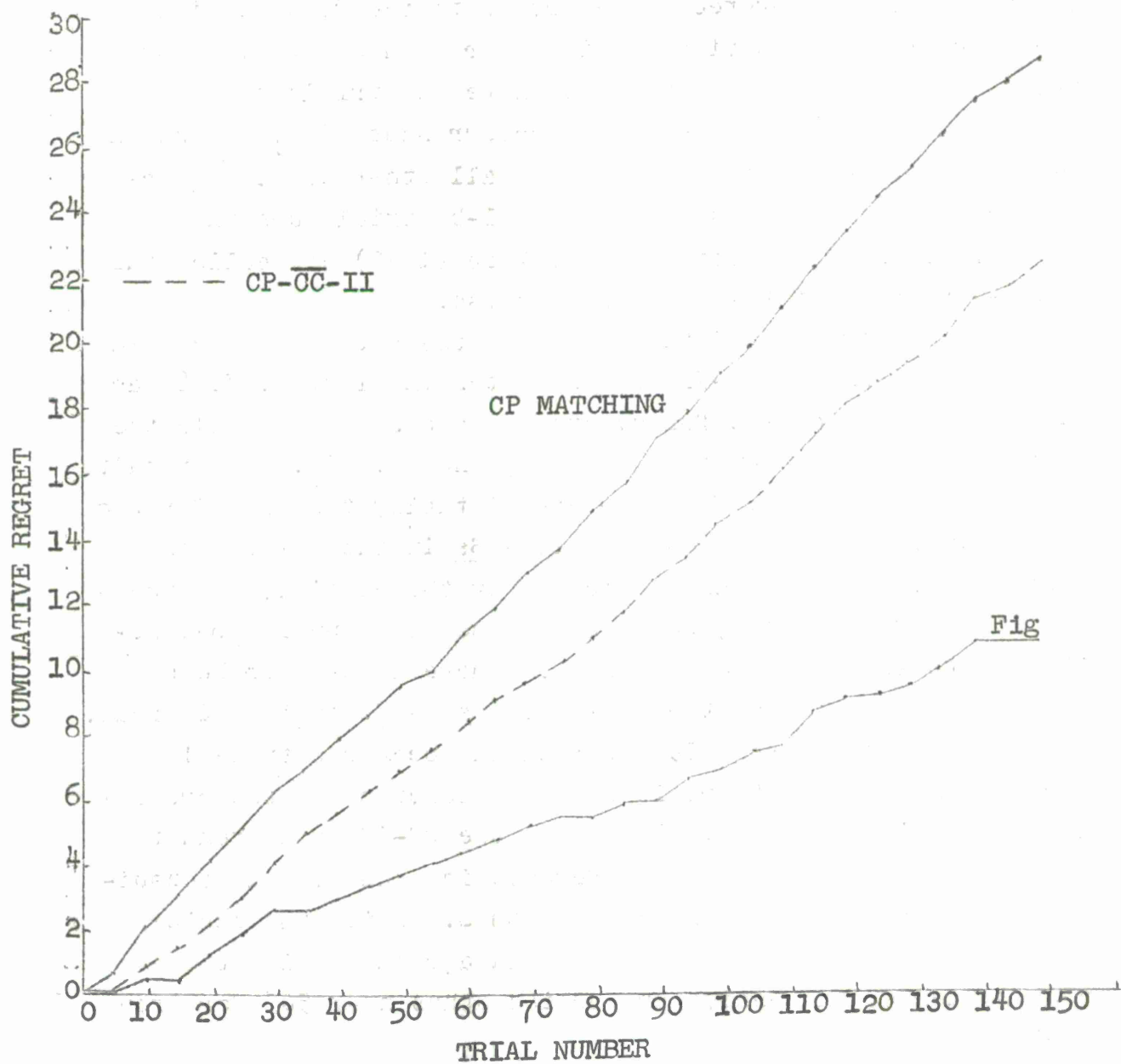


Fig. 4. Cumulative regret function evaluated at 5-trial intervals for Groups CP-CC-II ($N = 24$) and CP-CC-Fig. ($N = 32$).

The sources of differences in the corresponding regret functions are discovered by reference to the figures giving the proportions of optimal choices for each symptom. (The trial numbers in each figure designate the trials on which the stimulus was presented. The occurrences of E_1 are shown near the bottom of each figure. On all other trials E_0 occurred.) These figures present trial-by-trial guessing curves. Such curves reflect what Toda (1962) has called the macro-structure of the guessing process.

The proportions of the Ss making the optimal choices in Groups CC-FF and CP-CC-FF are presented in Figs. 6, 7, 8, and 9. The optimal choice for symptoms H and S is E_1 , while the optimal choice for symptoms N, F, D, and B is E_0 . The results for symptoms H, B, N, F, and D are virtually the same for the two groups. During the early trials Ss in the CP-CC group tend to give the response indicated by the conditional probabilities for symptom N, while Ss in the CC group respond according to the sequence of events. There appears to be some pattern seeking during the early trials by Ss in the CC group. When E_1 occurs on trial 29 after having occurred twice in succession earlier, there is a large reduction in the proportion of optimal choices. The Ss in the CP-CC group tend to be influenced by the large difference in conditional probabilities for the two events for symptom S. While the choice proportion for Group CC goes to 0% in agreement with the event sequence, the choice proportion stays near 50% for Group CP-CC.

The proportions of Ss making the optimal choices for Groups CC-FI and CP-CC-FI are presented in Figs. 10, 11, 12, and 13. The results for each symptom are quite similar for

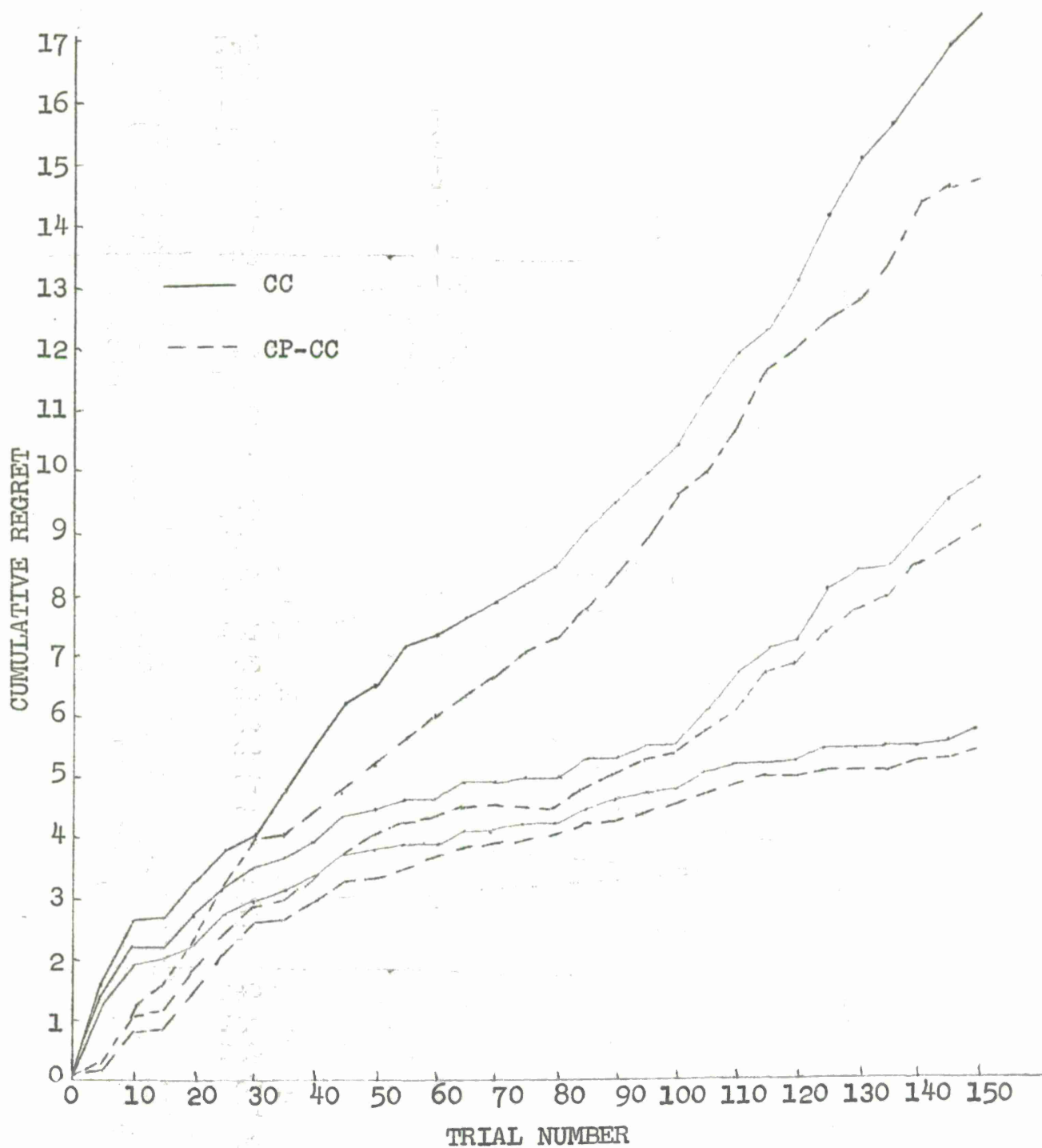


Fig. 5. Cumulative regret function for Groups CC-FF (N = 19), CP-CC-FF (N = 12), CC-FI (N = 10), CP-CC-FI (N = 12), CC-II (N = 19), CP-CC-II (N = 23).

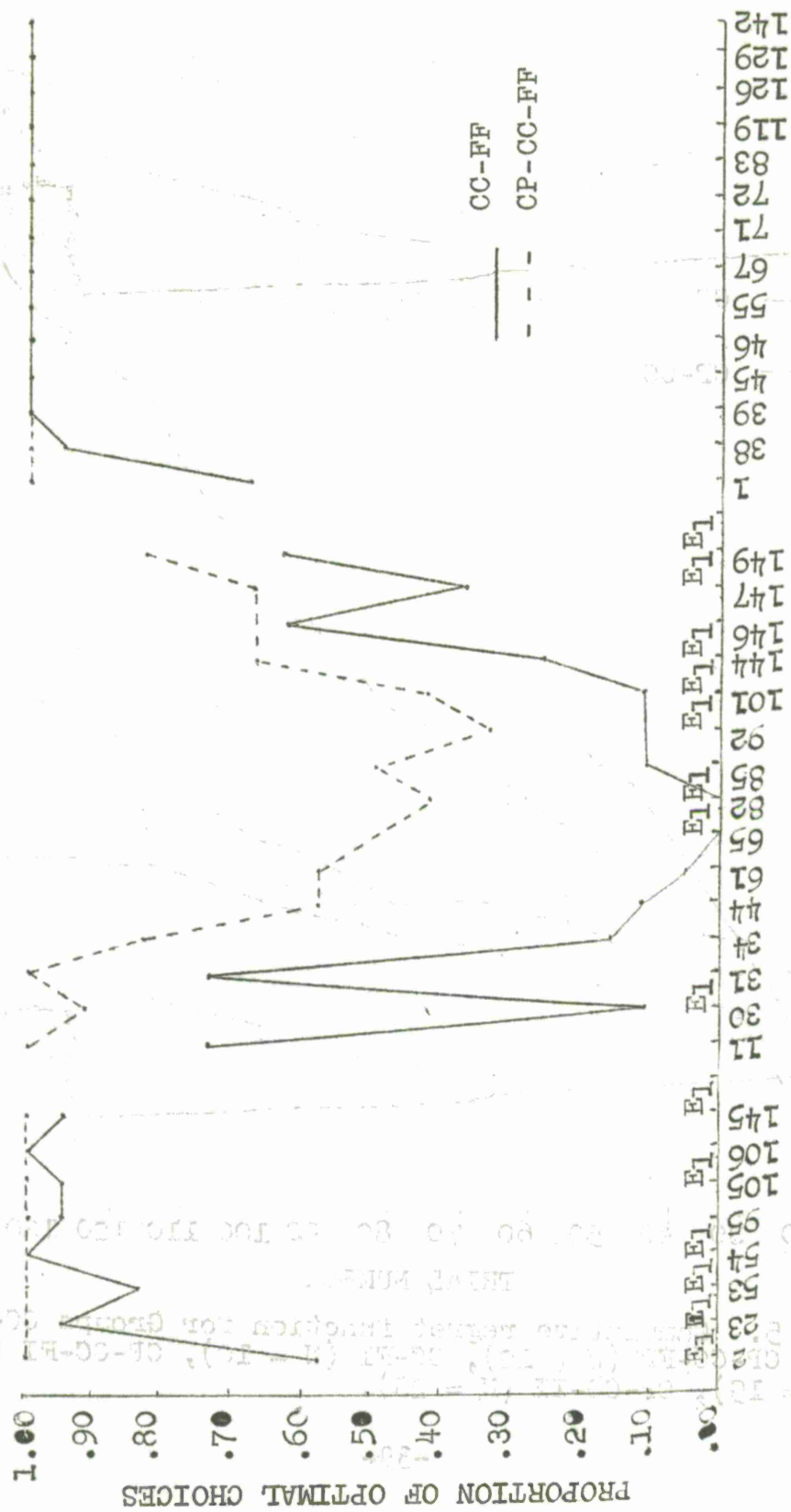


Fig. 6. Proportion of Ss making optimal choice for symptoms Headache, Sore Throat, and Backache. Groups CC-FF (N = 19) and CP-CC-FF (N = 12). The trials on which E₁ occurred are marked near the bottom of the figure.

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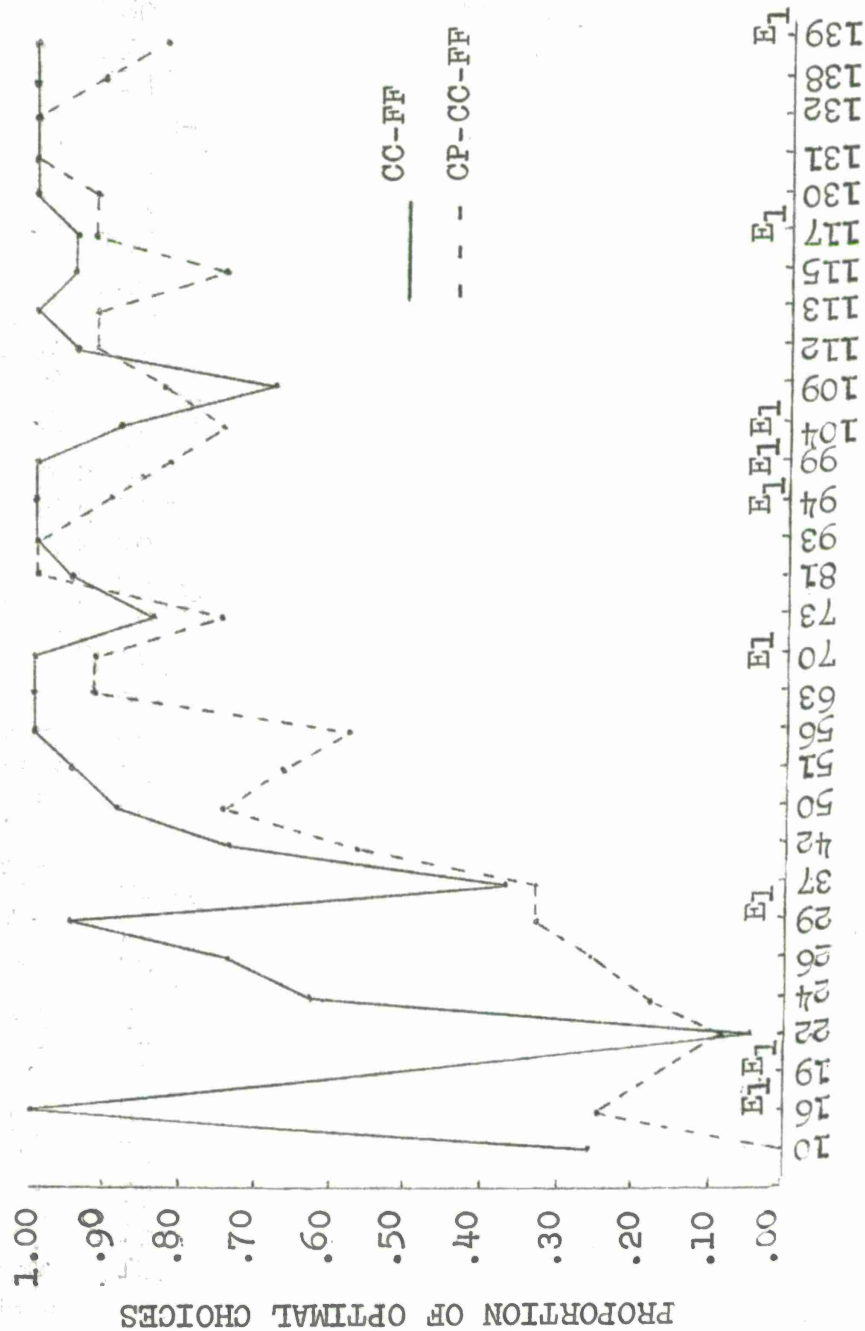


Fig. 7. Proportion of Ss making optimal choice for symptom Nausea. Groups CC-FF (N = 19) and CP-CC-FF (N = 12). The trials on which E₁ occurred are marked near the bottom of the figure.

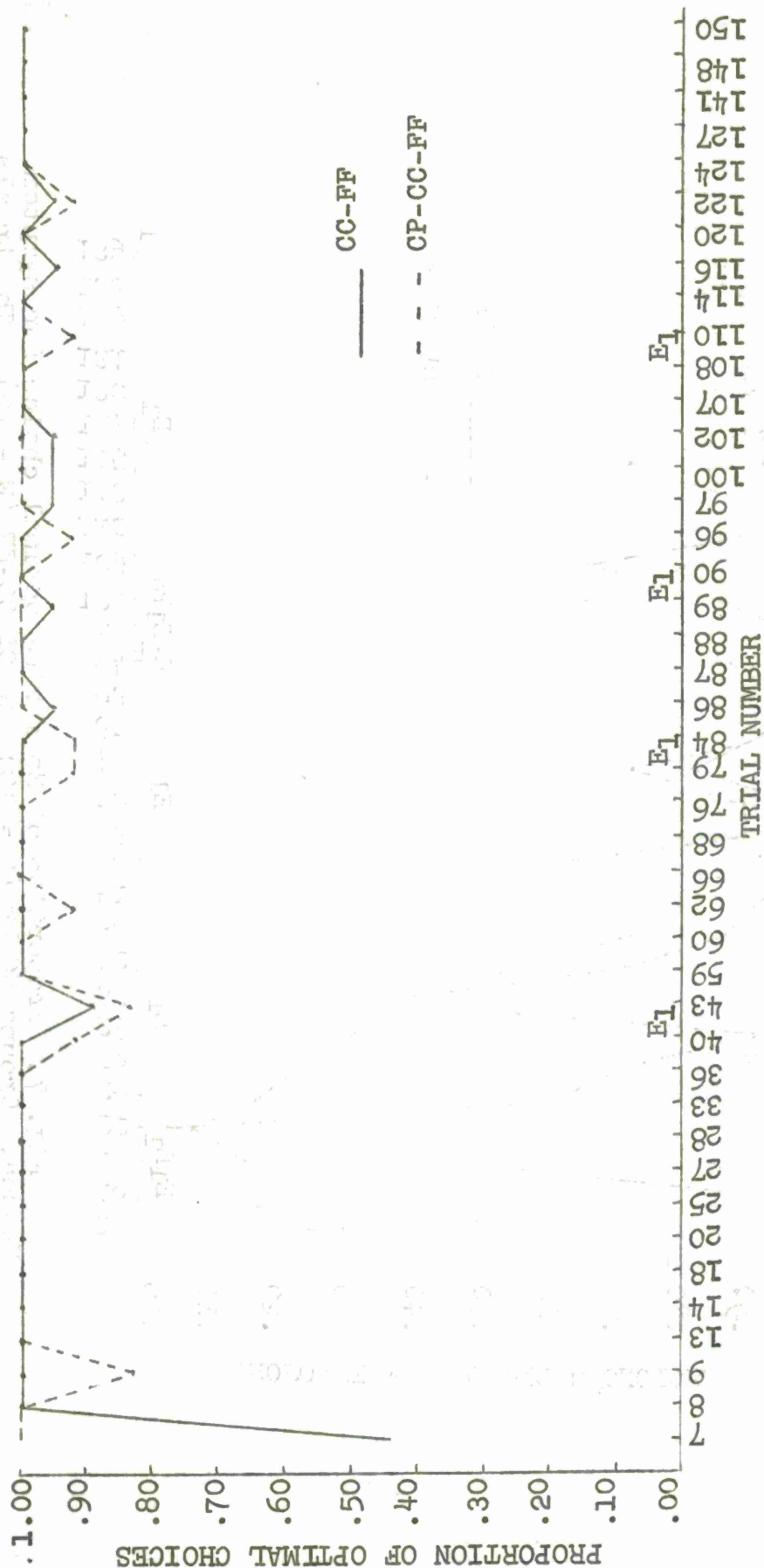


Fig. 8. Proportion of Ss making optimal choice for symptom fever. Groups CC-FF ($N = 19$) and CP-CC-FF ($N = 12$). The trials on which E_1 occurred are marked near the bottom of the figure.

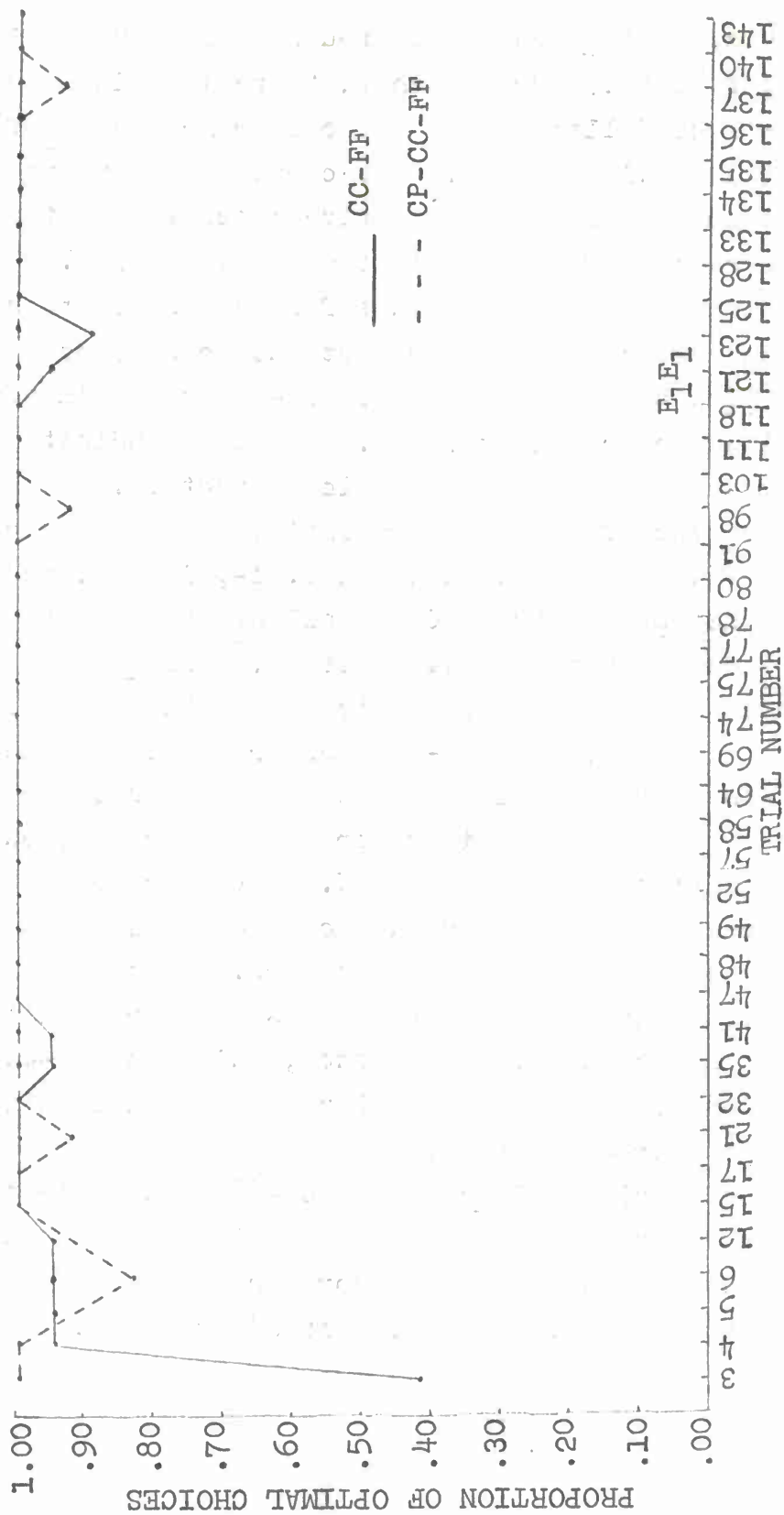


Fig. 9. Proportion of Ss making optimal choice for symptom Drowsiness. Groups CC-FF (N = 19) and CP-CC-FF (N = 12). The trials on which E_1 occurred are marked near the bottom of the figure.

these two groups. The Ss in these groups tend to be influenced by local factors. For instance, there is a large positive recency effect following the two occurrences of E_1 for symptom D on trials 118 and 121. The choices for symptom N are quite erratic with the same positive recency effect after the three occurrences of E_1 on trials 94, 99, and 101. The choice proportions for the two groups for symptom S are somewhat closer than are the choice proportions for the same symptom for the FF Ss, but the Ss in Group CP-CC are influenced by the conditional probability ratio. The data indicate that Ss in these groups are influenced by local factors.

The proportions of Ss making optimal choices for Groups CC-II and CP-CC-II are presented in Figs. 14, 15, 16, and 17. Fig. 14 shows that Ss in Group CC-II call A_1 for symptom B even though E_0 has occurred on every trial. The Ss in Group CP-CC-II tend to make the choice indicated by the conditional probabilities while Ss in the CC-II group respond at a level somewhat less than probability matching. The results for symptoms F and D are quite similar for the two groups, but there is a big difference in symptom N. In this case, Ss in the CP-CC-II group choose E_1 for the most part, while Ss in the other group choose E_0 for the most part. In essence the CC-II choice proportions for symptom N resemble probability matching according to the event sequence, while the CP-CC-II choice proportions resemble probability matching according to the conditional probabilities.

As mentioned earlier 32 Ss in the CP-CC group made the choice indicated by the conditional probabilities on each trial. Since the optimal choice proportions for these Ss are 0% for symptom N and 100% for the other symptoms, figures

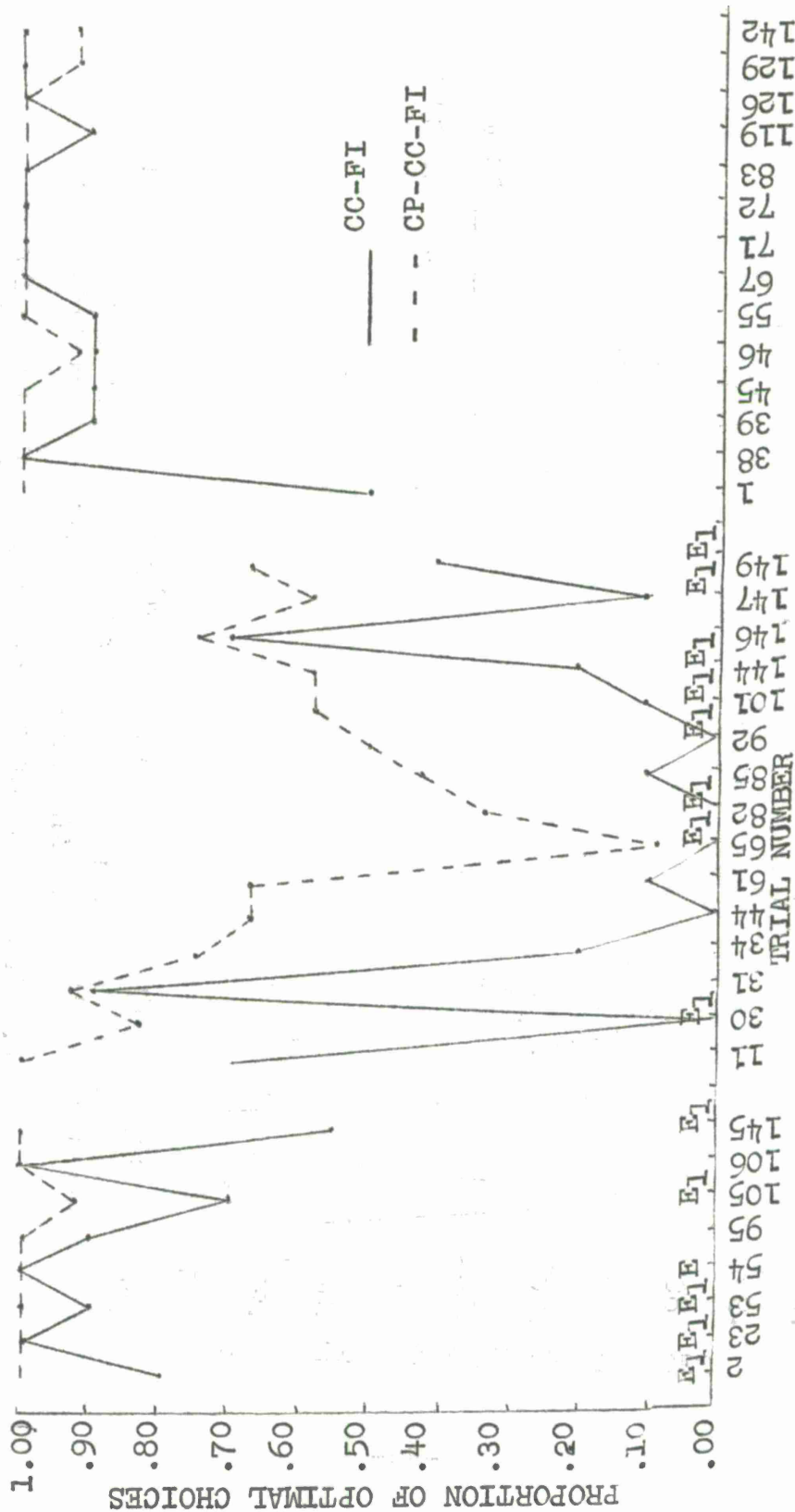


Fig. 10. Proportion of Ss making optimal choice for symptoms Headache, Sore Throat, and Backache. Groups CC-FI (N = 10) and CP-CC-FI (N = 12). The trials on which E₁ occurred are marked near the bottom of the figure.

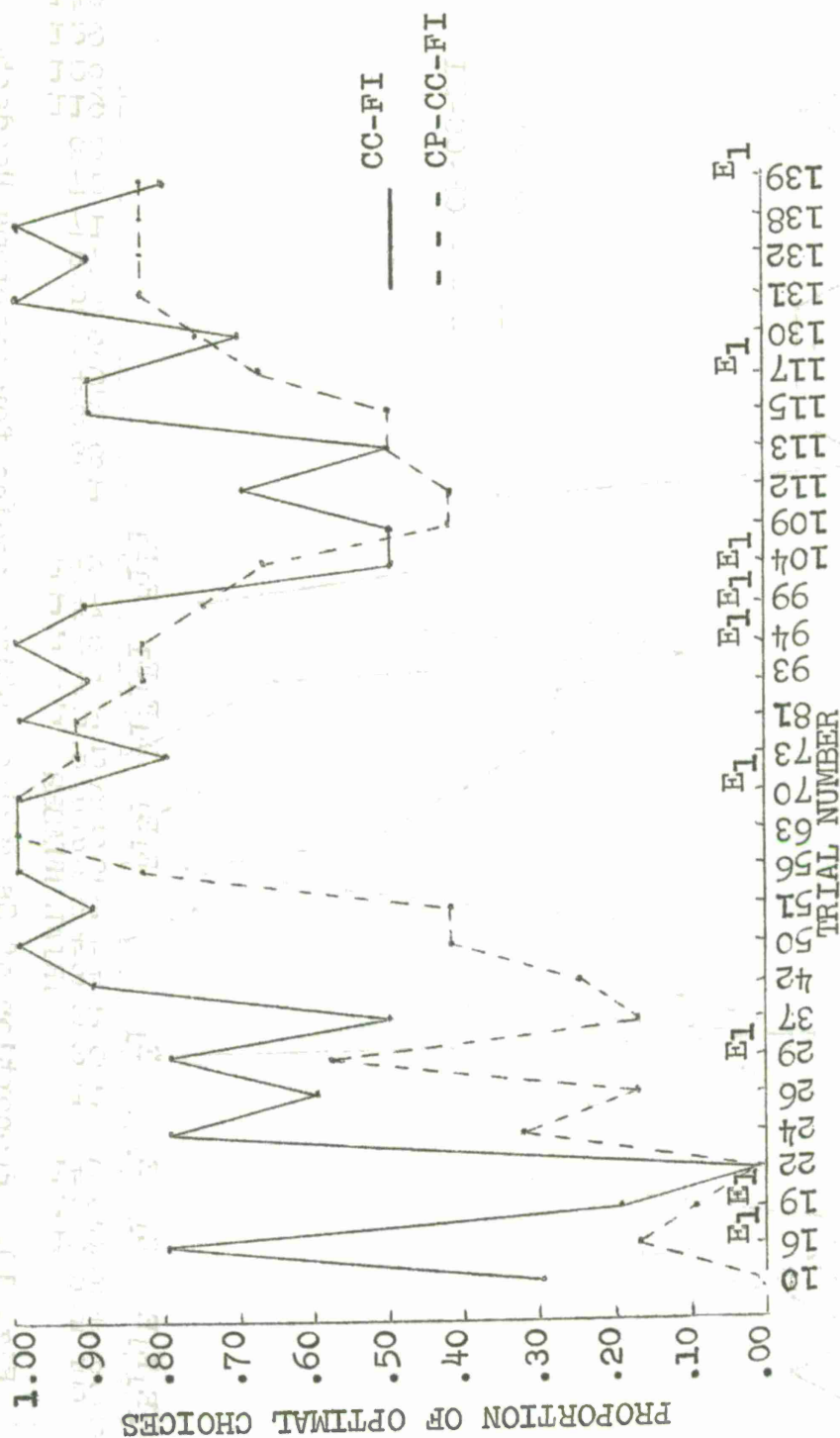


Fig. 11. Proportion of Ss making optimal choice for symptom Nausea. Groups CC-FI (N = 10) and CP-CC-FI (N = 12). The trials on which E₁ occurred are marked near the bottom of the figure.

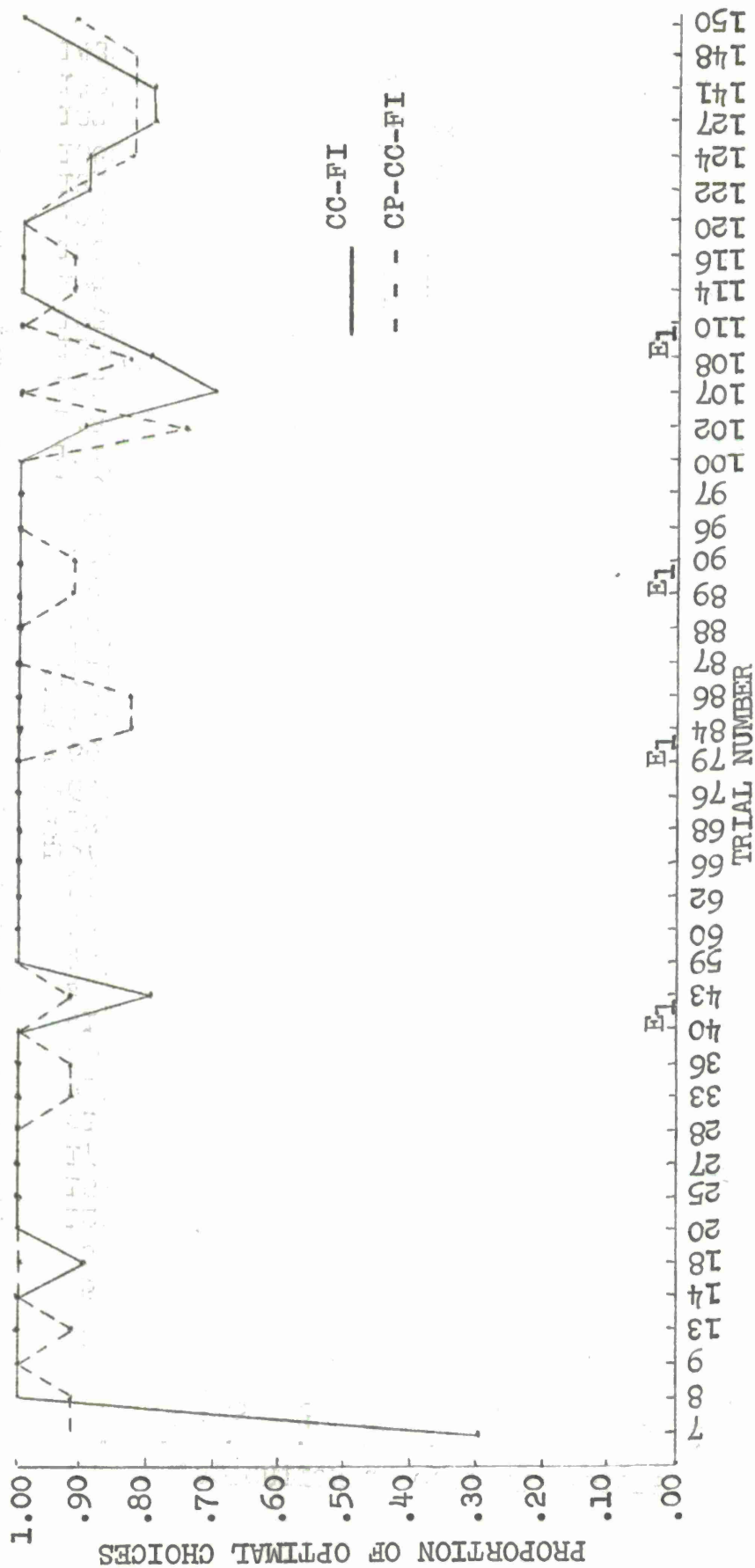


Fig. 12. Proportion of Ss making optimal choice for symptom fever. Groups CC-FI ($N = 10$) and CP-CC-FI ($N = 12$). The trials on which E_1 occurred are marked near the bottom of the figure.

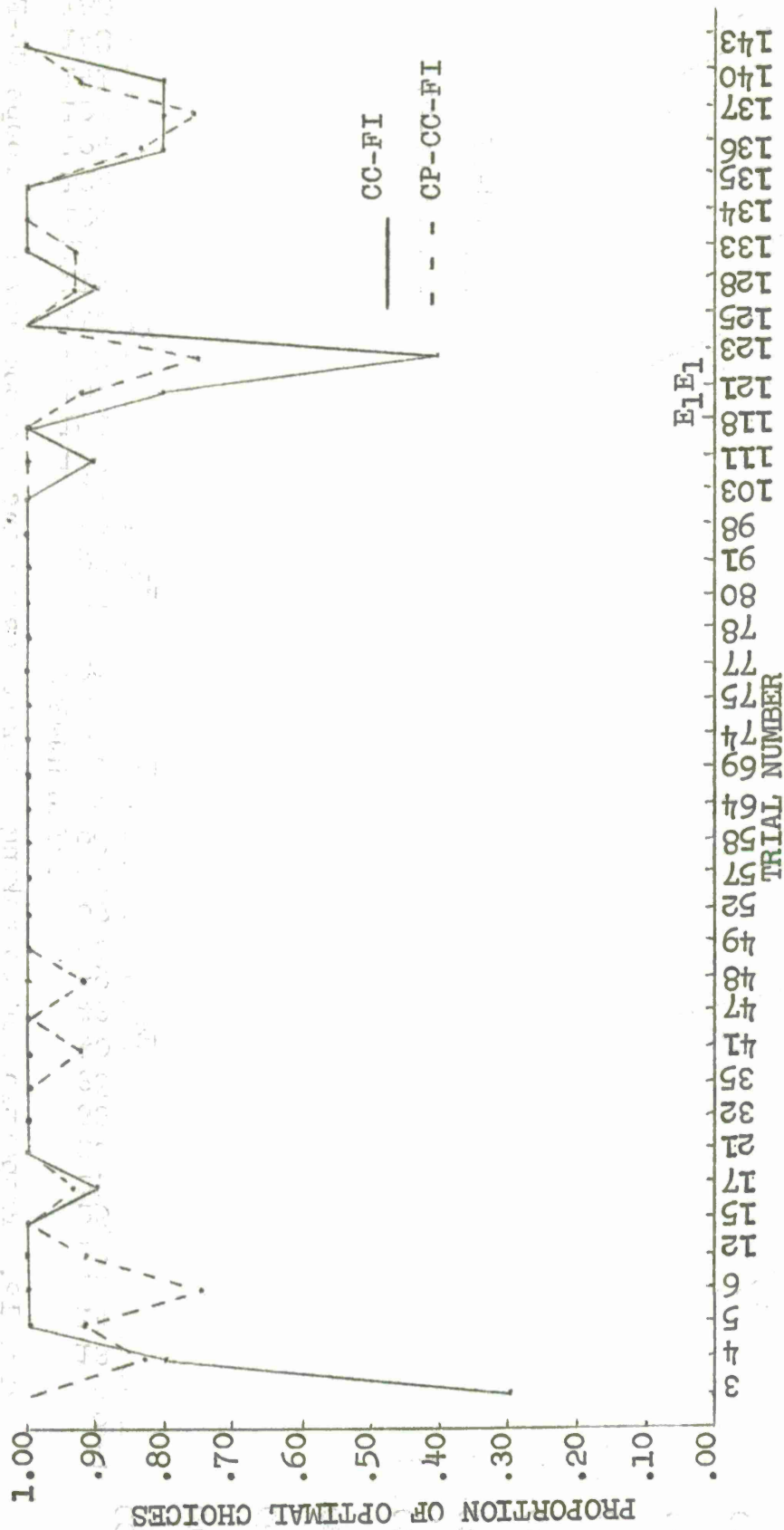


Fig. 13. Proportion of Ss making optimal choice for symptom Drowsiness. Groups CC-FI ($N = 10$) and CP-CC-FI ($N = 12$). The trials on which E_1 occurred are marked near the bottom of the figure.



Fig. 14. Proportion of Ss making optimal choice for symptoms Headache, Sore Throat, and Backache. Groups CC-II (N = 19) and CP-CC-II (N = 23). The trials on which E_1 occurred are marked near the bottom of the figure.

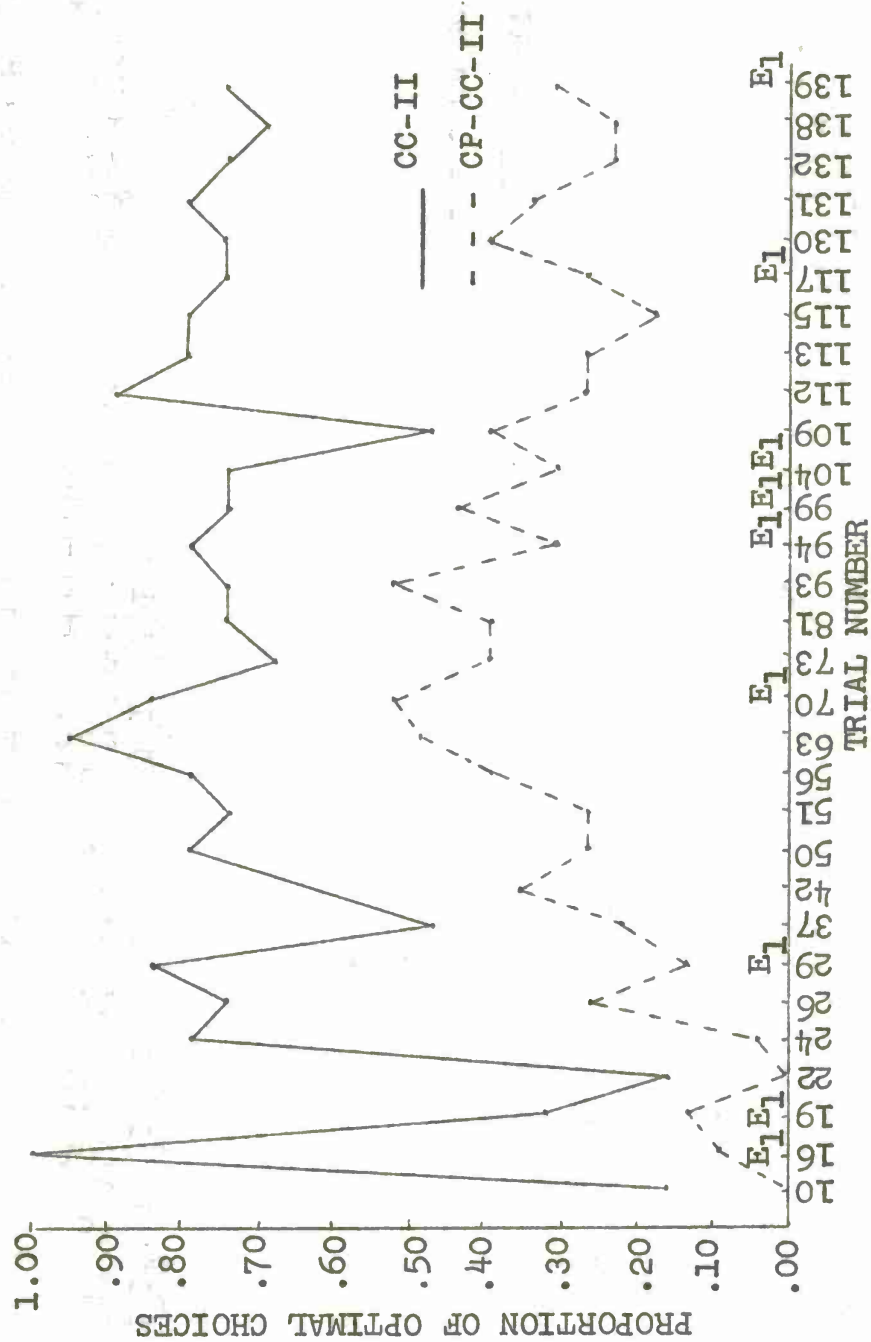


Fig. 15. Proportion of Ss making optimal choice for symptom' Nausea. Groups CC-II (N = 19) and CP-CC-II (N = 23). The trials on which E₁ occurred are marked near the bottom of the figure.

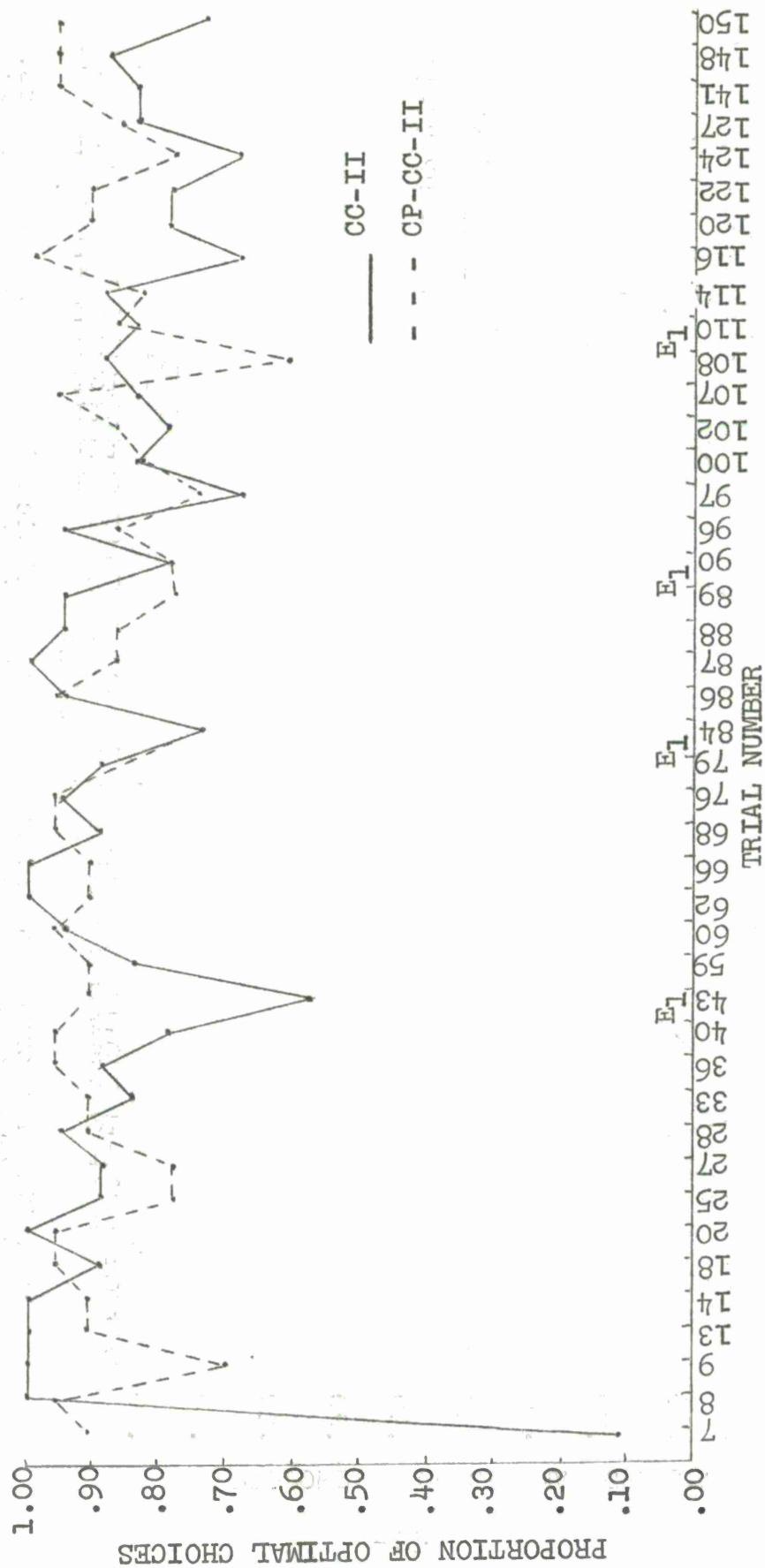


Fig. 16. Proportion of Ss making optimal choice for symptom Fever. Groups CC-II (N = 19) and CP-CC-II (N = 23). The trials on which E_1 occurred are marked near the bottom of the figure.

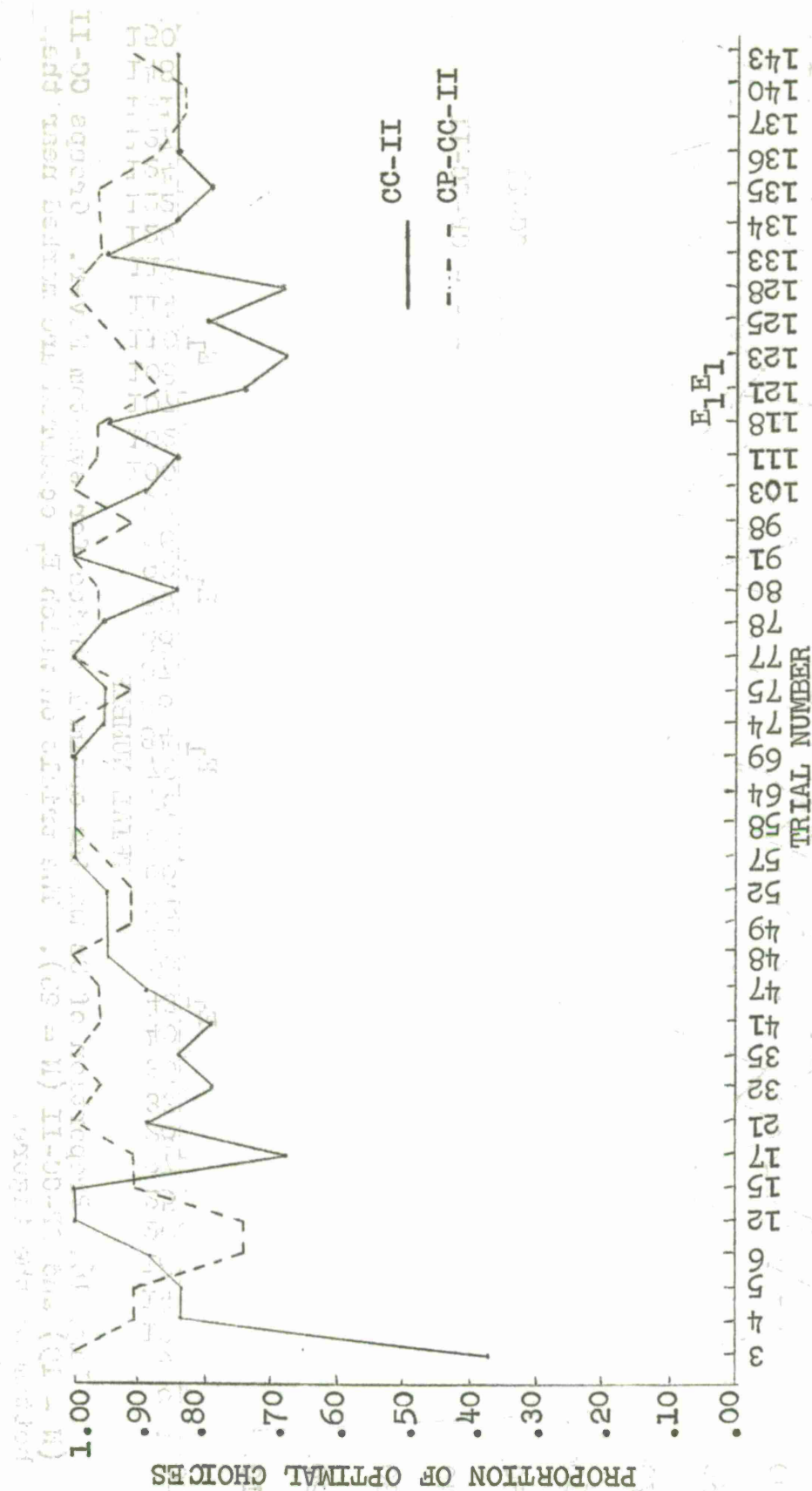


Fig. 17. Proportion of Ss making optimal choice for symptom Drowsiness. Groups CC-II ($N = 19$) and CP-CC-II ($N = 23$). The trials on which E_1 occurred are marked near the bottom of the figure.

showing these proportions are not presented. One S called A_1 for the first two presentations of symptom N, but made the optimal choice on all other trials. The choice proportions for the remaining Ss ($N = 24$) are presented in Figs. 18, 19, 20, and 21. Inspection of these figures shows that the proportion of optimal choices center around the CP-Matching lines for symptoms H, S, B, and N. The choice proportions for symptoms F and D are somewhat above the CP-Matching lines. This result indicates that Ss in Group CP-CC-II apportion their responses for each symptom according to choice proportions approximately equal to those obtained from the conditional probabilities.

It was stated earlier that δ_{11} should be equal to one-half for each symptom. Although no strong argument is to be made here for any assumption, it is rather interesting to look at the choice proportions for the first occurrence of each stimulus. By trial 11 all stimuli had occurred at least once. The proportion of Ss who chose A_0 on each of the first 11 trials is presented in Table 2. The stimulus and event sequences up to trial 11 are also presented.

The evidence here favors the suggestion that most Ss choose the response which has not been called correct for the other symptoms. Of course, from the nature of the instructions the Ss are justified in expecting E_1 to occur for some of the symptoms.

The information obtained from the questions asked after the experiment provide little information relevant to the analysis at this level. These results will not be presented.

TABLE 2

PROPORTION OF S_s CHOOSING E_0 ON THE FIRST 11 TRIALS

Trial	Symptom	Proportion	Event
1	B	<u>.58</u>	E_0
2	H	<u>.37</u>	E_1
3	D	.38	E_0
4	D	.88	E_0
5	D	.92	E_0
6	D	.94	E_0
7	F	<u>.28</u>	E_0
8	F	1.00	E_0
9	F	1.00	E_0
10	N	<u>.23</u>	E_0
11	S	<u>.25</u>	E_0

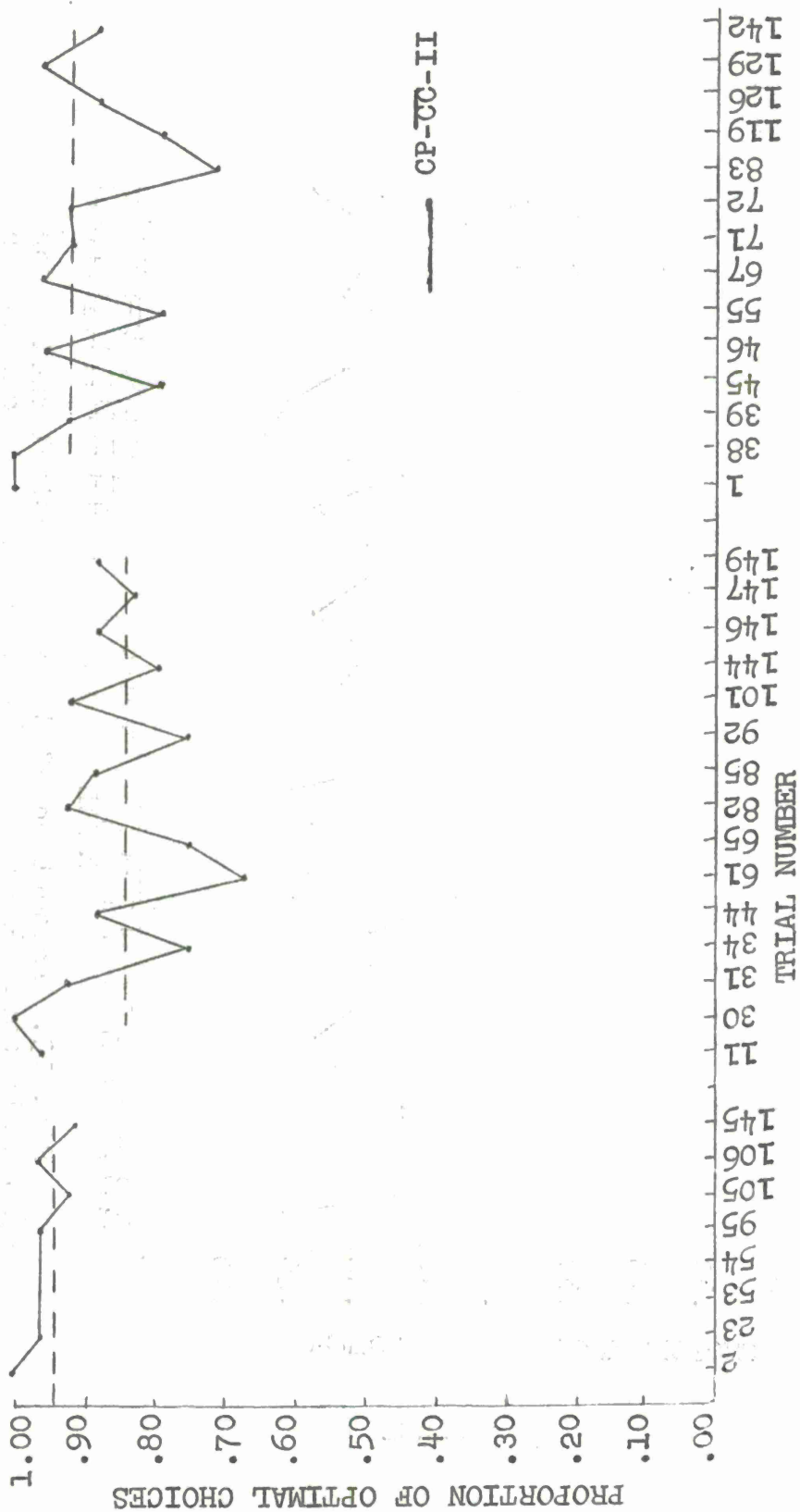


Fig. 18. Proportion of Ss making optimal choice for symptoms Headache, Sore Throat, and Backache. Group CP-CC-II ($N = 24$). The dashed lines are the CP Matching lines.

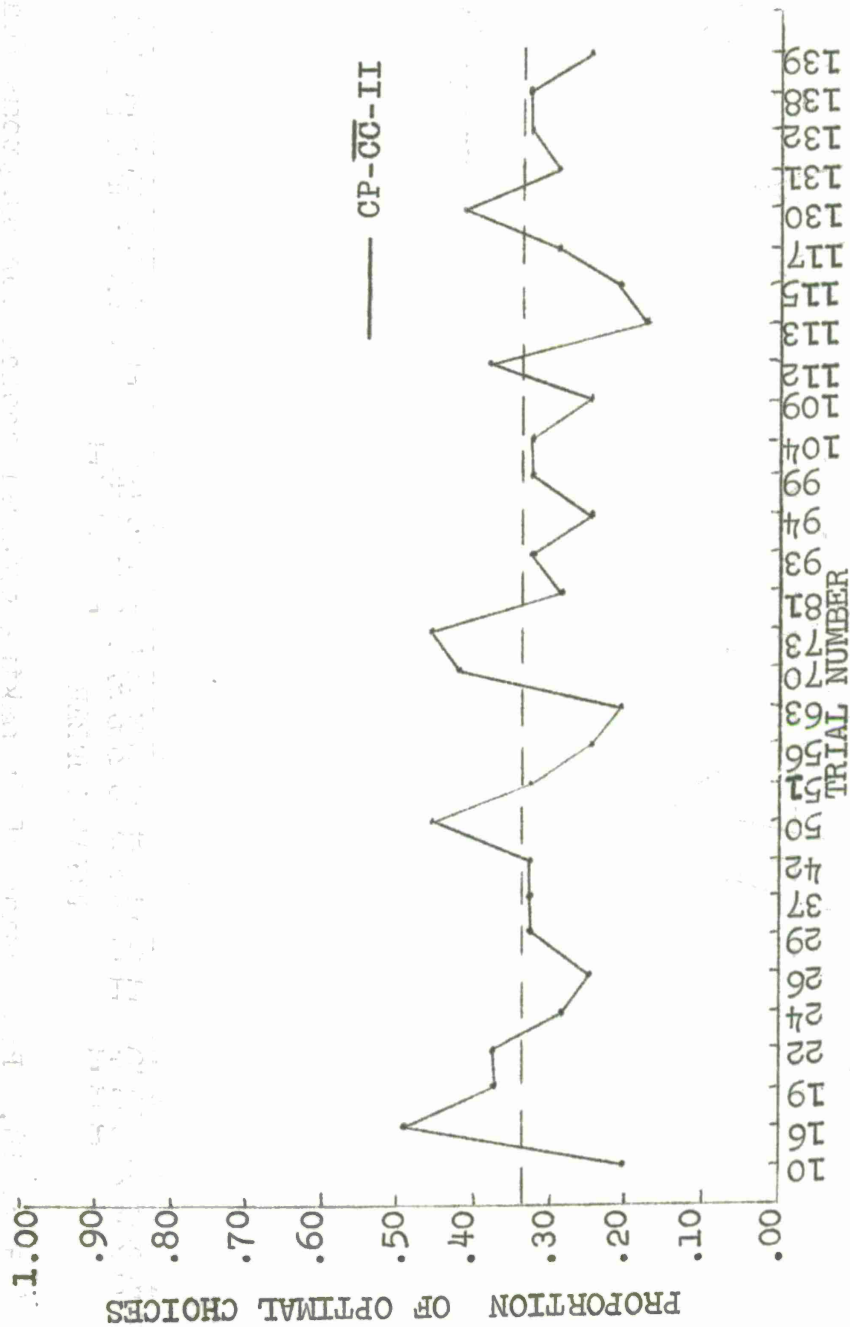


Fig. 19. Proportion of Ss making optimal choice for symptom: Nausea. Group CP-CC-II (N = 24). The dashed line is the CP Matching line.

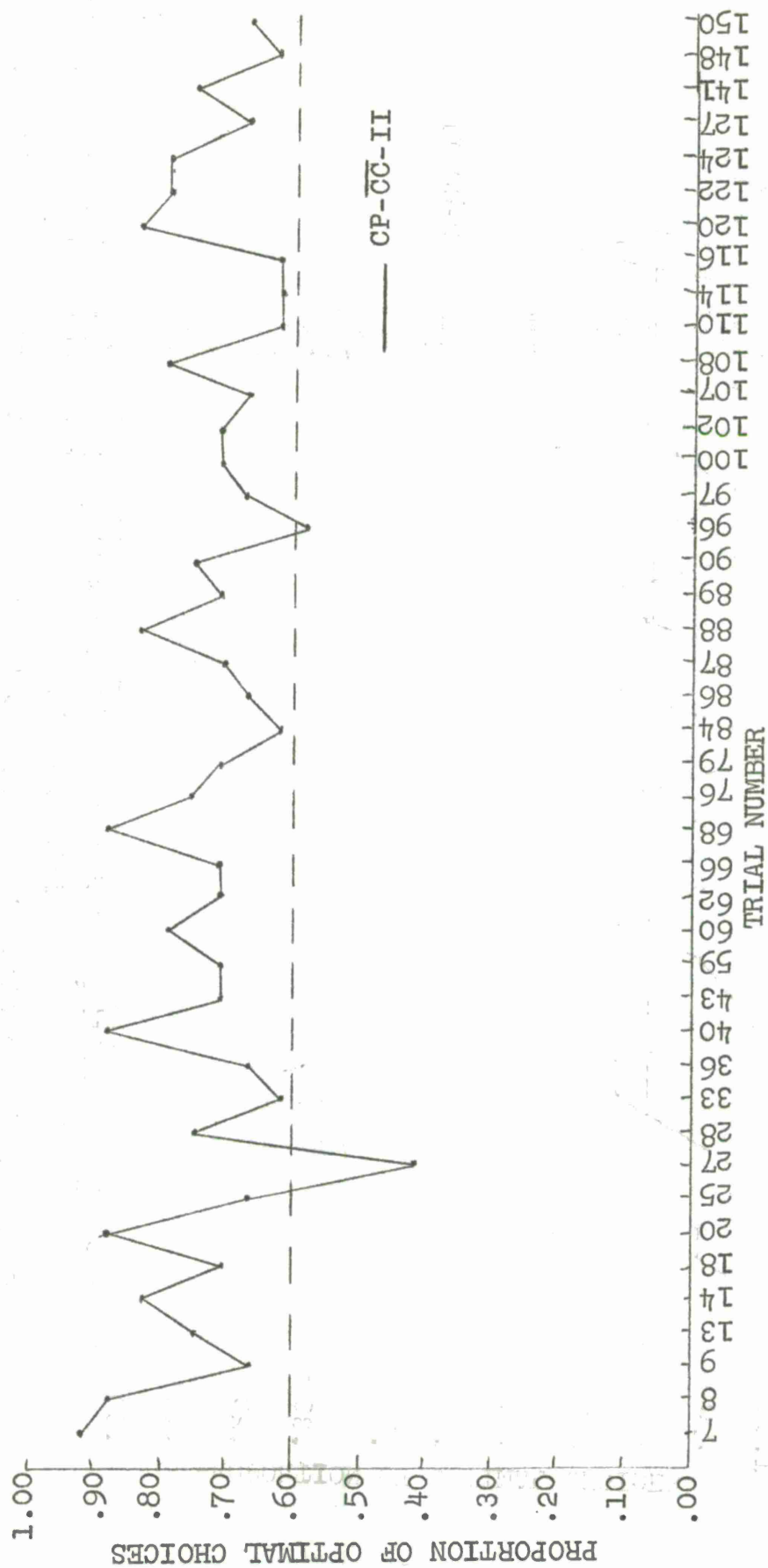


Fig. 20. Proportion of Ss making optimal choice for symptom fever. Group CP-CC-II (N = 24). The dashed line is the CP Matching line.

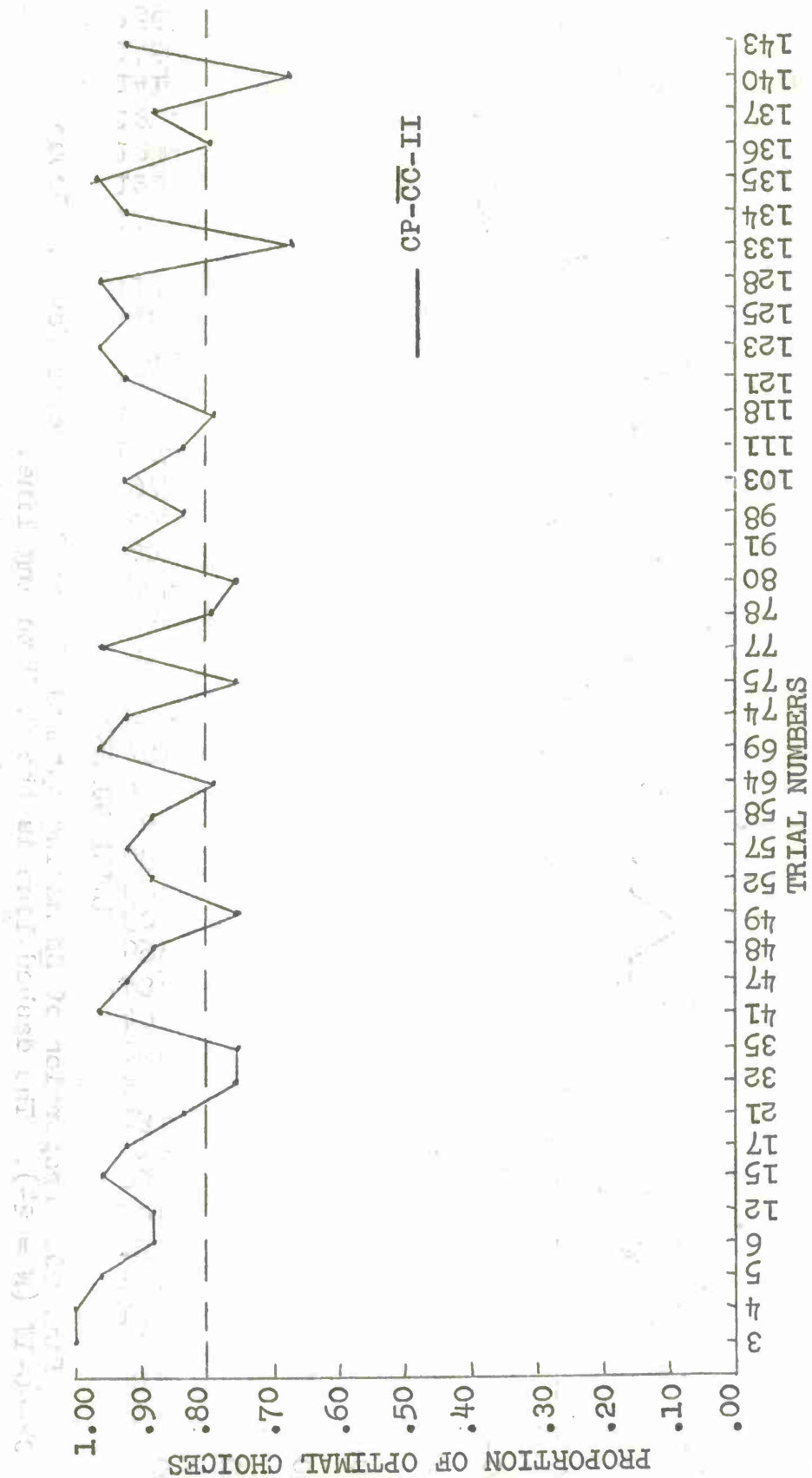


Fig. 21. Proportion of Ss making optimal choice for symptom Drowsiness.
Group CP-CC-II (N = 24). The dashed line is the CP Matching line.

CHAPTER V

DISCUSSION AND SUMMARY

The conclusions which can be drawn from the present investigation depend upon the level of data analysis. First, restricting attention to the cumulative regret functions based on the responses of all Ss in each group, there is quite a discrepancy between the performance of the Ss and the performance of the optimal model for each condition. There is little difference between the performance of the group in the prototypic probabilistic discrimination learning condition (Group CC) and the group in the task modified by presentation of the conditional probabilities of the stimuli given the events (Group CP-CC). The performance of the group in the condition where the conditional probabilities are given, but the correct choices are withheld, (Group CP- \overline{CC}) is poorer than the performance of the other groups.

Logically, the CC condition and the Cp-CC conditons are alike in every aspect except that the conditional probabilities are presented in the CP-CC condition. Presentation of the conditional probabilities should improve performance over that of the CC condition, but the results indicate that this is not the case. The degree to which performance is improved by presentation of the conditional probabilities is a function of the initial distribution. If the initial prior distribution is the large variance uniform distribution, it requires but a few observations to move $\bar{\pi}_1$ over the critical value for choosing A_0 for

symptom N. However, as the variance of this distribution decreases, it requires more observations to significantly change $\bar{\Pi}_k$. This would suggest that the differences between the two groups could be made greater if the prior distribution for Ss in the CP-CC group could be experimentally controlled. For instance, if a series of similar decision tasks were presented with the value of Π_0 being chosen for each task from some distribution known to S, one would be better able to assess the difference between performance in the two conditions.

It was suggested earlier that Ss differ with respect to the decision rule employed. Direct evidence for this suggestion has been obtained in similar tasks such as those reported by Toda (1962). The large individual differences found in the present experiment support this contention. Certainly, it is difficult to conceive that such differences could be the result of variation within a unitary process. The memory burden has been relieved by allowing S to keep a record of stimuli and events. There was little possibility for misidentification of stimuli or events. The major source of individual differences lies in the decision rule adopted by different Ss. There is nothing here which will help to decide why an S chooses one decision rule over another, or why he may have changed decision rules from time to time. The choice and change of decision rule are related to S's original perception of the task which he is to perform, to changes which occur in his perception of the task as a function of experience, to his motivation, to his willingness to use any mental effort to formulate a rule which has some chance of success, and to many other processes which are neither fully controlled nor understood. Classifying Ss according to the shape of the regret function does not lead to groups of Ss who use the same de-

cision rule, but the differences are at least reduced, and the result is a clearer picture of the differences between the CC and CP-CC groups.

More information about these differences can be obtained from the groups classified as FF than from the other groups because the method of classification assures that the responses of these Ss must be mostly optimal responses. The conclusion which seems most warranted is that there is not a clear understanding on the part of the Ss concerning the roles of overall frequency and conditional probabilities. The initial persistence in choosing A_1 for symptom N is consistent with the idea of an initial prior distribution with small variance, but the change in response proportion over trials for symptom S is not consistent with this idea. Granted that differences exist between the equations and numbers used by the models and the potentially analogous processes used by the Ss, and that there remains a possibility for a process similar to the decision rule developed for condition CP-CC, the more parsimonious interpretation consistent with the data is that the determinants of choice are the ratio of the two conditional probabilities and the event sequence for each symptom. That is, the Ss in the Cp-CC-FF group do not seem to take advantage of the fact that the only information relevant to the choice is the overall frequency of E_0 . On the other hand, the Ss in the FF groups appear to treat the task as it is constructed. That is, they seem to realize that the nature of the event sequence is stochastic, and they are usually not disturbed by the occurrences, even in groups, of the less frequently occurring event for a particular symptom.

The conditional probability matching which arises from the data of Ss in the CP-CC group classified as II is rather

interesting, but somewhat mysterious. The result is somewhat consistent with probability learning phenomena. However, it is doubtful that it could ever arise as a prediction from probability learning theory. Although Simon (1957) presents conditions which produce probability matching as behavior consistent with a minimax regret criterion (not regret as defined earlier in this paper), the derivation rests on the knowledge of results. Of course, the Ss in this group were not told which event occurred on each trial.

More intriguing, perhaps, is the fact that over half of the Ss in the group responded consistently in agreement with the conditional probabilities. How does this come about? An interesting analysis of behavior under conditions of reduced validation is presented by Bruner, Goodnow and Austin (1957). One task which they consider is a probabilistic categorization task which is very similar to the task used in this experiment. The primary difference is that certain aspects of presented objects provide partially valid cues for the purpose of categorization, but more than one cue is associated with each object. They suggest that reduction of opportunity to validate choices will lead to a reduction in problem solving activity in the sense of an attempt to eliminate error. This reduction in problem solving activity, they suggest, might lead to an all-or-none type of behavior in which a certain margin of error will come to be accepted.

Reference to the statistical structure of the present task yields some rather interesting facts. Figure 22 presents the expected number of errors in 150 trials for certain strategies as a function of π_0 . The two lines labeled " A_0 " and " A_1 " show the expected number of errors if S always chooses

the indicated response. For instance, if π_0 is zero and S always chooses A_0 , he is always wrong; while if π_0 is one, he is always correct. The curve labeled "optimal" gives the expected number of errors if π_0 is known and the optimal choice is always made for each stimulus. The function labeled " $\pi_0 = 1/2$ " gives the expected number of errors when the choice made for each stimulus is in agreement with the assumption that π_0 is one-half.

The interesting facts are that the expected number of errors is approximately constant and that there is a considerable region in which the difference between the expected number of errors for the "optimal" curve and the " $\pi_0 = 1/2$ " function is negligible.

This does not explain the behavior of Ss who always make the choice consistent with the assumption that $\pi_0 = 1/2$. There was some evidence that Ss in the CP-CC condition did not understand the role of the overall frequency in making their choices. If this is the case, the fact that there would be little gain from trying to learn π_0 if the decision maker were quite convinced that it was somewhere near one-half does not bear on the issue either. What seems to happen is that S does not seek a better solution but uses a strategy which, perhaps, he feels cannot be too disastrous.

It would be very interesting to see what would happen in the CP- \overline{CC} condition if the Ss were told beforehand the value of π_0 . Certainly if it were 0 or 1, there would be no question. However, if it were some other number, there would be a direct opportunity to investigate the ability of Ss to combine the conditional and prior probabilities. As mentioned before Edwards (personal communication) has found Ss unable to do this in an estimation task.

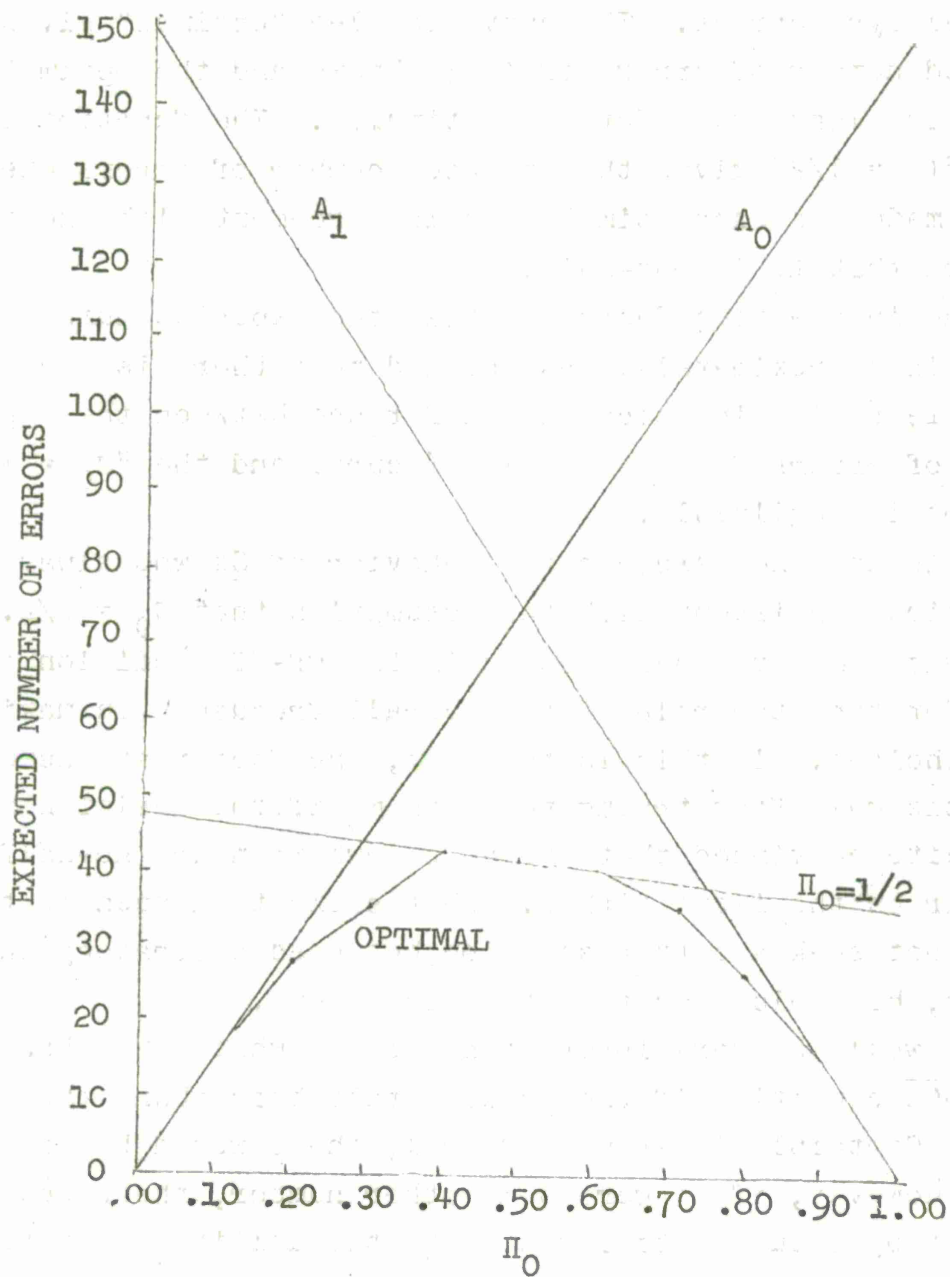


Fig. 22. Expected number of errors as a function of Π_0 for three different strategies.

The primary concern here is not whether a certain strategy can be interpreted as "rational" or "irrational." Certainly, if all the constraints, both external in the sense of the properties of the decision task and internal in the sense of the ability of the humans to perform certain functions, his motivation, the cost to him for seeking out a more satisfactory solution, etc., were known, one would find that his behavior was consistent with these constraints. In the work reported here, the effect of manipulating certain external constraints has been analyzed. In order to make this analysis it has been necessary to assume that the internal environment of S is such that his goal is the achievement of expected payoff and that he is capable of integrating information about overall frequency and conditional probabilities. The first assumption is obviously too simple, the second may or may not be valid. However, the analysis which is possible from these assumptions is helpful in understanding the logical differences of certain choice situations and provides a sound basis for comparing the performances of Ss who perform in these choice situations.

Summary.--A decision-theoretic analysis of three related choice situations is presented. The first situation is a standard probabilistic discrimination learning situation (CC). In this situation each trial begins with the presentation of one of a set of six stimuli. The S must choose between two response alternatives (A_0 or A_1) to indicate which of two events (E_0 or E_1) he feels will occur on the trial. After making his choice, S is told which of the events occurred. The second situation (CP-CC) arises when the conditional probabilities, the probabilities of the stimuli given the events, are introduced to S at the beginning of the experiment. The

third situation differs from the second only in that S is not told which event occurred on each trial.

The decision-theoretic analysis shows what decision rule should be used in each situation in order to maximize expected payoff. This analysis shows what differences in performance would be expected among the three conditions, in terms of a strategy designed to maximize expected payoff.

In the (CC) condition, S must keep track of the relative frequency of E_0 events for each stimulus. In the CP-CC and CP- \overline{CC} conditions the conditional probabilities are given at the beginning of the experiment. Since Bayes Rule can be used to obtain the posterior probabilities, the only relevant information to be extracted from the sequence of events in these conditions is the overall relative frequency of E_0 events. The differences between these two conditions are a function of the source of this information. Knowledge of which event occurred on each trial is the source of this information for the CP-CC condition. For the CP- \overline{CC} condition the source of this information is the conditional probabilities of the stimuli which have occurred.

One group of Ss was run in each condition with the overall relative frequency of E_0 equal to .80. The performance of the CC group was virtually identical to that of the CP-CC group, while the performance of the CP- \overline{CC} group was somewhat worse, where the performance measure was the difference between the objective expected payoff of the optimal choice and the choice made by S on each trial.

When the performance curve for each S was sketched, the presence of very significant individual differences indicated that a more meaningful analysis could be obtained by classify-

ing each S in one of three subgroups on the basis of the observed increase in the performance curve after the initial trials. The proportion of optimal choices for each trial was computed for each subgroup of each condition. Although there were differences among the subgroups, comparisons of the choice proportions of corresponding subgroups across conditions for the CC and CP-CC groups indicated that Ss in the Cp-CC group did not integrate information concerning the overall relative frequencies of events and conditional probabilities.

The data from the CP- \overline{CC} group revealed that a large proportion of Ss made every choice in agreement with an assumption that the overall relative frequency of E_0 was one half. This led to mediocre performance. The performance of the other Ss in this group was worse; the choice proportions of this group reflected probability matching on the basis of the conditional probabilities.

APPENDIX I

DECISION-THEORETIC ANALYSIS OF CHOICE SITUATIONS

The three choice situations to be analyzed here have the following aspects in common:

1.) There exist two events, E_0 and E_1 . On each trial one and only one of these events occurs. The probability that E_0 occurs on each trial, π_0 , is constant and the trials are independent.

2.) The value of π_0 is unknown to the \underline{S} in the choice situation.

3.) The \underline{S} does not know, at the beginning of a trial, which event occurred. Rather, he sees a stimulus on each trial and must decide which event produced or generated the stimulus. If he decides E_0 was the event, he chooses A_0 , and if he decides E_1 was the event, he chooses A_1 .

4.) The stimuli form an exhaustive set of mutually exclusive elements. $S_1 = \{s_1, s_2, \dots, s_n\}$.

5.) The distribution of stimuli depends only upon E_j , the event which occurs. The distribution of stimuli is $f(s_1|E_0)$ for E_0 and $f(s_1|E_1)$ for E_1 . When E_0 occurs on a given trial a stimulus is selected at random according to the scheme $P_r(S = s_1|E_0) = f(s_1|E_0)$, and similarly for E_1 .

6.) The payoff to \underline{S} for choosing alternative A_j given that event E_j occurred is independent of the stimulus and is given in the matrix

	E_0	E_1
A_0	u_1	u_2
A_1	u_2	u_1

The only restriction is that $u_1 > u_2$.

These are the boundary conditions common to all three choice situations. In order to proceed it is necessary to specify the performance criterion which is to be adopted. The performance criterion to be used here is the maximization of expected payoff.

The objective expected payoff for choosing A_0 when s_1 occurs is

$$\begin{aligned} (1) \quad E[p(A_0)|s_1] &= u_1 P'(E_0|s_1) + u_2 [1 - P'(E_0|s_1)] \\ &= P'(E_0|s_1)(u_1 - u_2) + u_2 \end{aligned}$$

The choice which maximizes objective expected payoff is the choice A^* such that

$$(2) \quad E[p(A^*)|s_1] - E[p(A_0)|s_1] \geq 0.$$

or when $P'(E^*|s_1) - P'(E_0|s_1) \geq 0$.

Hence, for the payoff matrix under consideration, the choice is determined by the event which has the greater probability given the stimulus. It will change nothing to consider a payoff matrix with unity in the main diagonal and zeros elsewhere, and doing this will simplify the exposition.

The three choice situations or decision tasks to be discussed here arise as the conditional probabilities and/or exact knowledge of the event which occurred on each trial are provided or withheld.

Task CC--- In this situation S knows the possible stimuli to be presented, but does not know the conditional distributions. After making his choice on each trial, he is told which event occurred.

Since S does not know the conditional probabilities, he has no real basis for assuming that any particular subset of the stimuli is such that A_0 is the best choice for these stimuli and that A_1 is the best choice for the other stimuli. The S should treat each stimulus as a separate decision task and keep a separate account of the sequence of events for each stimulus.

For instance, consider stimulus s_1 . Since \underline{S} does not know $P'(E_0|s_1)$, some method must be used which will account for \underline{S} 's uncertainty concerning the proportion of E_0 events associated with s_1 . One way to do this is to expand the decision problem in such a way that the states of nature are defined as the possible proportions of E_0 events, for stimulus s_1 , which the experiment might have chosen. Then, if \underline{S} always chooses A_0 for s_1 , his payoff, in the long run, will be equal to the product of $P'(E_0|s_1)$ and the number of times stimulus s_1 is presented. Potentially, any number in $(0,1)$ could have been chosen for $P'(E_0|s_1)$, and \underline{S} is uncertain as to which value was actually selected. In order to express this uncertainty, define a prior distribution, $g(\rho_1)$, on $(0,1)$. Here, the random variable P_1 represents the possible values of $P'(E_0|s_1)$. Assuming that very little information will be required for \underline{S} to change his opinion concerning the true value of $P'(E_0|s_1)$, $g(\rho_1)$ will be represented by the uniform distribution on $(0,1)$, and will be written as a beta distribution with parameters $(r' = 1, n' = 2)$. Then \underline{S} 's expected payoff for choosing A_0 when s_1 is presented is

$$E[p(A_0)|s_1] = \int_0^1 \rho_1 d\rho_1 = 1/2$$

after stimulus s_1 has been presented $(k-1)$ times, E_0 has occurred r times and E_1 has occurred $(k-1-r)$ times. In \underline{S} 's view the probability of an E_0 event on any trial is some fixed, but unknown, number, ρ_1 and the trials are independent. The distribution of E_0 events is then binomial with $(k-1, \rho_1)$ and the posterior distribution of P_1 is

$$g(\rho_1|r, k-1, r', n') = \frac{1}{B(r'+r, n'-r'+k-1-r)} \rho_1^{r'+r-1} (1-\rho_1)^{n'-r'-1+(k-1)-r}$$

The expected payoff to \underline{S} for choosing A_0 on trial k is

$$\begin{aligned} E'[p(A_0)|s_1] &= \frac{1}{B(r'+r, n'-r'+(k-1)-r)} \int_0^1 \rho_1^{r'+r} (1-\rho_1)^{n'-r'-1+(k-1)-r} d\rho_1 \\ &= \frac{r'+r}{n'+k-1} = \delta_{1k} \end{aligned}$$

the mean of the beta posterior distribution. Since \underline{S} makes his choice so as to maximize expected payoff, he uses the following decision rule.

DECISION RULE (CC)

Choose A_0 whenever $\delta_{1k} \geq 1/2$

Choose A_1 whenever $\delta_{1k} \leq 1/2$

Choose A_0 with probability $1/2$ and A_1 with probability $1/2$ whenever $\delta_{1k} = 1/2$.

The subscript 1 refers to the stimulus and k refers to the number of times that particular stimulus has been presented.

Task CP-CC--- In this task the conditional probabilities, $P'(s_1|E_1)$ are presented to S at the beginning of the experiment. The S is told which event occurred after he has made his choice on each trial.

If π_0 , the proportion of E_0 events, is assumed to be one half, the choice with the greater probability of leading to a correct decision is the one which is indicated by the conditional probabilities. That is, A_0 is chosen if $P'(s_1|E_0) \geq P'(s_1|E_1)$ and A_1 is chosen otherwise. (The task is constructed so that $P'(s_1|E_0) \neq P'(s_1|E_1)$, for $i = 1, 2, \dots, n$.)

In this case S 's uncertainty can be coded as uncertainty concerning the value of π_0 . Again this uncertainty will be represented by a beta distribution on $(0,1)$. The random variable is Π , the potential values of π_0 , and the probability density function is $\frac{1}{B(\alpha, \beta)} \pi^{\alpha-1} (1-\pi)^{\beta-1}$.

Consider S 's choice on the ℓ th trial. A stimulus is presented which will be called stimulus $s_{1\ell}$ to designate the member of the stimulus set which was presented and the trial number on which it was presented. What choice does S make? Since his choice is determined by the event which he feels is more likely to occur, it is necessary to consider $P_\ell(E_0|s_{1\ell}, \underline{s}_{\ell-1}, \underline{E}_{\ell-1})$, the probability of event E_0 on the ℓ th trial given the stimulus for that trial and the preceeding history of stimuli and events. This represents the probability, to S , that event E_0 will occur on the ℓ th trial. This probability is

$$(3) P_\ell(E_0|s_{1\ell}, \underline{s}_{\ell-1}, \underline{E}_{\ell-1}) = \frac{P(s_{1\ell}|E_0, \underline{s}_{\ell-1}, \underline{E}_{\ell-1}) P_\ell(E_0|\underline{s}_{\ell-1}, \underline{E}_{\ell-1})}{\sum_{j=0,1} P(s_{1\ell}|E_j, \underline{s}_{\ell-1}, \underline{E}_{\ell-1}) P_\ell(E_j|\underline{s}_{\ell-1}, \underline{E}_{\ell-1})}$$

In (3) $\underline{s}_{\ell-1}$ is the vector of stimuli which occurred on the first $(\ell-1)$ trials, and $\underline{E}_{\ell-1}$ is the vector of events which occurred on the first $(\ell-1)$ trials.

The first term in the numerator on the right in (3) is

$$(4) \quad P(s_{1\ell} | E_0, \underline{s}_{\ell-1}, \underline{E}_{\ell-1}) = P'(s_{1\ell} | E_0)$$

since the distribution of stimuli is completely specified when the event is given.

The second factor in the numerator is $P_\ell(E_0 | \underline{s}_{\ell-1}, \underline{E}_{\ell-1})$ and is

$$(5) \quad P_\ell(E_0 | \underline{s}_{\ell-1}, \underline{E}_{\ell-1}) = \int_0^1 \pi g(\pi | \underline{s}_{\ell-1}, \underline{E}_{\ell-1}) d\pi$$

since $P_\ell(E_0 | \pi, \underline{s}_{\ell-1}, \underline{E}_{\ell-1}) = P(E_0 | \pi) = \pi$

In turn

$$g(\pi | \underline{s}_{\ell-1}, \underline{E}_{\ell-1}) = \frac{f(\underline{s}_{\ell-1}, \underline{E}_{\ell-1} | \pi) g(\pi)}{\int_0^1 f(\underline{s}_{\ell-1}, \underline{E}_{\ell-1} | \pi) g(\pi) d\pi}$$

Since the event is independently and randomly selected on each trial and, once known, completely specifies the distribution of stimuli

(6)

$$g(\pi | \underline{s}_{\ell-1}, \underline{E}_{\ell-1}) =$$

$$\frac{P'(s_{11}, E_1 | \pi) P'(s_{12}, E_2 | \pi) \cdots P'(s_{1, \ell-1}, E_{\ell-1} | \pi) g(\pi)}{\int_0^1 P'(s_{11}, E_1 | \pi) P'(s_{12}, E_2 | \pi) \cdots P'(s_{1, \ell-1}, E_{\ell-1} | \pi) g(\pi) d\pi}$$

But

$$(7) \quad P'(s_{1k}, E_k | \pi) = P'(s_{1k} | E_k, \pi) P(E_k | \pi)$$

$$= P'(s_{1k} | E_0) \pi$$

$$\text{if } E_k = E_0$$

$$= P'(s_{1k} | E_1) (1-\pi)$$

$$\text{if } E_k = E_1$$

for $k = 1, 2, \dots, (\ell - 1)$.

Substituting the appropriate terms from (7) into (6), the terms $P'(s_{ik}|E_0)$ and $P'(s_{ik}|E_1)$ cancel in numerator and denominator since these terms, not involving π in the denominator, can be taken outside the integral sign. Equation (6) then becomes

$$(8) \quad g(\pi|\underline{s}_{\ell-1}, \underline{E}_{\ell-1}) = \pi^r(1-\pi)^{\ell-1-r}g(\pi) / \int_0^1 \pi^r(1-\pi)^{\ell-1-r}g(\pi)d\pi,$$

where r is the number of times E_0 has occurred up through trial $(\ell - 1)$.

Substituting (8) into (5) gives

$$(9) \quad P_{\ell}(E_0|\underline{s}_{\ell-1}, \underline{E}_{\ell-1}) = \frac{\int_0^1 \pi^{r+1}(1-\pi)^{\ell-1-r}g(\pi)d\pi}{\int_0^1 \pi^r(1-\pi)^{\ell-1-r}g(\pi)d\pi}.$$

Since $g(\pi)$ is a beta distribution, the expression in (9) is the mean of a beta posterior distribution where the data generating process is binomial. This posterior distribution has parameters $(\alpha+r, \beta+\ell-1-r)$.

$$(10) \quad P_{\ell}(E_0|\underline{s}_{\ell-1}, \underline{E}_{\ell-1}) = \bar{\pi}_{\ell} = (r+\alpha)/(\ell-1+\alpha+\beta).$$

Substituting these results back into (3) the final result is

$$(11) \quad P_{\ell}(E_0|s_{1\ell}, \underline{s}_{\ell-1}, \underline{E}_{\ell-1}) = P'(s_{1\ell}|E_0)/\{P'(s_{1\ell}|E_0)\bar{\pi}_{\ell} + P'(s_{1\ell}|E_1)(1-\bar{\pi}_{\ell})\}.$$

The decision rule is

Choose A_0 whenever $P'(s_{1\ell}|E_0)\bar{\pi}_{\ell}/P'(s_{1\ell}|E_1)(1 - \bar{\pi}_{\ell}) > 1$,

Choose A_1 otherwise.

Rearranging and solving for $\bar{\pi}_{\ell}$, the decision rule can be written

Decision rule (CP-CC)

Choose A_0 whenever $\bar{\pi}_{\ell} > P'(s_{1\ell}|E_1)/\{P'(s_{1\ell}|E_1) + P'(s_{1\ell}|E_0)\}$.

Thus the distribution of π_{ℓ} depends only on the sequence of events up to the ℓ th trial, the initial prior distribution, and the stimulus which is presented on the ℓ th trial. The decision rule is fixed by the initial conditions, and $\bar{\pi}_{\ell}$ is the choice determinant.

Task CP-CC--- In this task \underline{S} is given the conditional probabilities, but he is not told which event occurred on each trial.

In this case the decision rule is the same as it is in the CP-CC task. The only difference is the distribution of π . The distribution for the CP- \overline{CC} is obtained in exactly the same manner as the distribution for the CP-CC task. The result, of course, is different since the actual sequence of events is not known. The result is

$$(12) \quad g(\pi | \underline{s}_\ell, \alpha, \beta) = \frac{\prod_{k=1}^{\ell} [P'(s_{1k} | E_0)\pi + P'(s_{1k} | E_1)(1-\pi)] \pi^{\alpha-1} (1-\pi)^{\beta-1}}{\int_0^1 \prod_{k=1}^{\ell} [P'(s_{1k} | E_0)\pi + P'(s_{1k} | E_1)(1-\pi)] \pi^{\alpha-1} (1-\pi)^{\beta-1} d\pi}.$$

The final result to be shown here is the sense in which $\overline{\pi}_\ell \rightarrow \pi_0$ as $\ell \rightarrow \infty$, assuming α and β to be finite. For r of the ℓ trials, the event will be E_0 , and for $(\ell - r)$ trials the event will be E_1 . Then

$$E(\pi | \underline{E}_\ell, \alpha, \beta) = (r + \alpha) / (\ell + \alpha + \beta) = \left(\frac{\ell}{\ell + \alpha + \beta} \right) \left(\frac{r}{\ell} \right) + \frac{\alpha}{\ell + \alpha + \beta}.$$

Since

$$\begin{aligned} \lim_{\ell \rightarrow \infty} [(\ell) / (\ell + \alpha + \beta)] &= 1, \\ \lim_{\ell \rightarrow \infty} [(\alpha) / (\ell + \alpha + \beta)] &= 0; \end{aligned}$$

convergence is assured by Bernoulli's Theorem (Brunk, 1960).

$\Pr\{|\frac{r}{\ell} - \pi_0| < \epsilon\} \rightarrow 1$ as $\ell \rightarrow \infty$, where ϵ is an arbitrarily small positive number. It is not possible for this author to show convergence of $\overline{\pi}_\ell$ to π_0 in the CP- \overline{CC} task.

APPENDIX II

GENERAL INSTRUCTIONS FOR EXPERIMENT

I am sure that at one time or another most, if not all, of you have visited a doctor for treatment of some ailment. You are undoubtedly aware that in some cases the doctor is not absolutely certain what the ailment is, but his job is to prescribe a treatment which he feels will cure the ailment. In this type of case the doctor has information from examinations and reported symptoms which may indicate several ailments. He recommends a treatment on the basis of information available, but he cannot be certain that his diagnosis is correct. It is obviously important to make the correct diagnosis as often as possible. When the diagnosis is incorrect, varied results may follow, but in any case, there is a penalty of some kind for being wrong.

I am interested in studying how people learn to make decisions in situations such as the one which I have just described. In order to study certain aspects of the learning process, I want each of you to place yourself in the role of a doctor who will be faced with a series of decisions in a situation which is far less complex than that which I have just described. Let me explain the situation.

There is a certain virus whose presence in an individual can be detected by the result of an analysis of a blood sample from the person. However, it is known that two strains of the virus exist, and that the blood test yields the same result no matter which strain of the virus is present. I will refer to the one strain as VIRUS Y, and to the other strain as VIRUS O. It is not possible that a single person is simultaneously affected with both strains.

It is important to try to establish which strain is present in a given individual in order that the proper treat-

ment can be given. One drug has been developed which is effective in curing a patient who has virus Y, while another drug has been developed which is effective in curing a patient who has virus O. Neither drug is effective against the other virus. It is not possible to administer both drugs to a single patient since the two drugs interact in a way which is often harmful. If the proper drug is administered, the patient will be well in a matter of a few hours. If the proper drug is not administered, the patient will be incapacitated for a few days, but will then recover. In any case, it is possible to tell which strain of the virus was present in the patient after a few days because of the reaction in the patient. Of course, it is then too late to change the treatment.

You see that it is important to make as many correct diagnoses as possible. If your decision is correct, the patient recovers quickly. He is able to continue his normal daily activities, and he is satisfied with your services. If you make the incorrect decision, the patient will be incapacitated for a few days. He is not able to perform his normal activities, and he is not very satisfied with your services. You will never be certain when you make a diagnosis, and you cannot be correct in every case. You should try to be correct as often as you can.

This experiment will consist of a series of trials. You should consider each trial as an occasion on which a patient is presented to you for diagnosis. From the result of the blood analysis you know that the patient has one of the two strains of virus. The patient reports a symptom which will help you in reaching a decision, but the symptom will not enable you to make a certain diagnosis.

ADDITIONAL INSTRUCTIONS FOR CC GROUP

As the experiment proceeds you may see that virus Y is associated with some symptoms more often than is virus O. On the other hand, you may see that virus O is associated with other symptoms more often than is virus Y. Your task is

make a choice on each trial and to try to be correct as often as you can.

These cards on the blackboard name the symptoms which will be reported. At the beginning of each trial I shall announce the trial number. I will then pick up one of these 3x5 cards. The name of the symptom reported by the patient is written on the card. I will read the name of the symptom and point to the appropriate card on the blackboard. You should enter the first letter of the symptom in the column headed SYMPTOM on your answer sheet. You should then make your decision. If you decide that the patient has virus Y, mark a Y in the column headed CHOICE. If you decide that the patient has virus O, mark an O in the column headed CHOICE. You will be given fifteen seconds to record the first letter of the symptom and to make and record your choice. Be sure that you make your choice within this time limit. We will have a few practice trials so that you can get used to the pacing.

After you have made and recorded your choice, that is, after the fifteen seconds, I will tell you which strain of virus the patient had. I will do this by reading the word on the 3x5 card which contained the symptom. I will also point to the appropriate card on the blackboard. Record this letter on your answer sheet in the column headed VIRUS. Five seconds after I have done this, I will proceed with the next trial.

Please do not try to see what choices your neighbors are making, and do not indicate by expression or sound whether you have made the correct or wrong choice on any trial. Do not become discouraged if you are wrong in some cases. It is impossible to be right in every case. Remember that it is important to be correct as often as you can.

Are there any questions concerning what you are supposed to do? Be sure to ask me now if you do not understand what you are to do.

We will now proceed with the practice trials. At the completion of these practice trials I will answer any further questions which you may have.

Are there any further questions? Be sure to ask any question which is related to what you are to do if you have any doubts.

ADDITIONAL INSTRUCTIONS FOR CP-CC GROUP

This figure on the blackboard will help you in making your decisions. Let me explain the meaning of this figure. Clinics throughout the country have kept records for thousands of patients who have had the virus in which we are interested. These records tell which strain of virus each patient had and which symptom was reported by the patient. As I have said before, it is possible to tell which strain of virus a particular patient had a few days after treatment has been administered. From all of these records, the records of a thousand patients who were known to have virus Y were selected and the records of a thousand patients who were known to have virus O were selected. This figure on the blackboard was prepared using these records.

Now consider only the records of the thousand patients who were known to have virus O. The height of the blue rectangle above each symptom is proportional to the number of patients with virus O who reported that symptom. For instance, of the thousand patients who had virus O more reported FEVER than any other symptom. DROWSINESS was the next most frequent symptom reported by the thousand patients who had virus O. Finally of the thousand patients who had virus O fewer reported HEADACHE than any other symptom.

Now consider only the records of the thousand patients who were known to have virus Y. The height of the red rectangle above each symptom is proportional to the number of patients with virus Y who reported that symptom. For instance, of the thousand patients who had virus Y more reported NAUSEA than any other symptom,

SORE THROAT was the next most frequent symptom reported by the thousand patients who had virus Y. Finally of the thousand patients who had virus Y fewer reported BACKACHE than any other symptom.

Although this figure is based upon the records of a thousand patients who were known to have virus Y and a thousand patients who were known to have virus O, it does not necessarily mean that it was as easy to get the thousand records for the one virus as for the other, easy in the sense that there may have been more patients who were found to have the one strain of virus than there were to have the other strain. You should consider the overall frequency of each strain of virus in making your decisions. Although a particular symptom may occur more frequently when one strain of virus is present than when the other strain is present, it does not necessarily follow that that first strain of virus is more likely when the symptom occurs. So, in making your diagnoses you should consider the overall frequency of each strain of virus.

You will get an idea of these frequencies since I will tell you which strain of virus each patient had after you have made and recorded your choice. Your task is to make a choice on each trial and to try to be correct as often as you can.

These cards on the blackboard name the symptoms which will be reported. At the beginning of each trial I shall announce the trial number. I will then pick up one of these 3x5 cards. The name of the symptom reported by the patient is written on the card. I will read the name of the symptom and point to the appropriate card on the blackboard. You should enter the first letter of the symptom in the column headed SYMPTOM on your answer sheet. You should then make your decision. If you decide that the patient has virus O, mark an O in the column headed CHOICE. If you decide that the patient has virus Y, mark a Y in the column headed CHOICE. You will be given fifteen seconds to record the first letter of

the symptom and to make and record your choice. Be sure that you make your choice within this time limit. We will have a few practice trials so that you can get used to the pacing.

After you have made and recorded your choice, that is, after the fifteen seconds, I will tell you which strain of virus the patient had. I will do this by reading the word on the 3x5 card which contained the symptom. I will also point to the appropriate card on the blackboard. Record this letter on your answer sheet in the column headed VIRUS. Five seconds after I have done this, I will proceed with the next trial.

Please do not try to see what choices your neighbors are making, and do not indicate by expression or sound whether you have made the correct or wrong choice on any trial. Do not become discouraged if you are wrong in some cases. It is impossible to be right in every case. Remember that it is important to be correct as often as you can.

Are there any questions concerning what you are supposed to do? Be sure to ask me now if you do not understand what you are to do.

We will now proceed with the practice trials. At the completion of these practice trials I will answer any further questions which you may have.

Are there any further questions? Be sure to ask any question which is related to what you are to do if you have any doubts.

ADDITIONAL INSTRUCTIONS FOR CP GROUP

This figure on the blackboard will help you in making your decisions. Let me explain the meaning of this figure. Clinics throughout the country have kept records for thousands of patients who have had the virus in which we are interested. These records tell which strain of virus each patient had and which symptom was reported by the patient. As I have said before, it is possible to tell which strain of virus a particular patient had a few days

after treatment has been administered. From all of these records, the records of a thousand patients who were known to have virus Y were selected and the records of a thousand patients who were known to have virus O were selected. This figure on the blackboard was prepared using these records.

Now consider only the records of the thousand patients who were known to have virus O. The height of the blue rectangle above each symptom is proportional to the number of patients with virus O who reported that symptom. For instance, of the thousand patients who had virus O more reported FEVER than any other symptom. DROWSINESS was the next most frequent symptom reported by the thousand patients who had virus O. Finally of the thousand patients who had virus O fewer reported HEADACHE than any other symptom.

Now consider only the records of the thousand patients who were known to have virus Y. The height of the red rectangle above each symptom is proportional to the number of patients with virus Y who reported that symptom. For instance, of the thousand patients who had virus Y more reported NAUSEA than any other symptom, SORE THROAT was the next most frequent symptom reported by the thousand patients who had virus Y. Finally of the thousand patients who had virus Y fewer reported BACKACHE than any other symptom.

Although this figure is based upon the records of a thousand patients who were known to have virus Y and a thousand patients who were known to have virus O, it does not necessarily mean that it was as easy to get the thousand records for the one virus as for the other, easy in the sense that there may have been more patients who were found to have one strain of virus than there were to have the other strain. You should consider the overall frequency of each strain of virus in making your decisions. Although a particular symptom may occur more frequently when one strain of virus is present than when the other strain is present, it does not

necessarily follow that the first strain of virus is more likely when the symptom occurs. So, in making your diagnoses you should consider the overall frequency of each strain of virus.

You will get an idea of these frequencies by paying attention to which symptoms occur more frequently. For instance, if FEVER, DROWSINESS and BACKACHE tend to occur quite frequently, it would indicate that virus O is occurring more frequently than is virus Y. On the other hand, if NAUSEA, SORE THROAT and HEADACHE tend to occur quite frequently, it would indicate that virus Y is occurring more frequently than is virus O. Your task is to make a choice on each trial and to try to be right as often as you can. At the end of the experiment I will tell you which virus each patient had.

These cards on the blackboard name the symptoms which will be reported. At the beginning of each trial I shall announce the trial number. I will then pick up one of these 3x5 cards. The name of the symptom reported by the patient is written on the cards. I will read the name of the symptom and point to the appropriate card on the blackboard. You should enter the first letter of the symptom in the column headed SYMPTOM on your answer sheet. You should then make your decision. If you decide that the patient has virus O, mark an O in the column headed CHOICE. If you decide that the patient has virus Y, mark a Y in the column headed CHOICE. You will be given fifteen seconds to record the first letter of the symptom and to make and record your choice. Be sure that you make your choice within this time limit. We will have a few practice trials so that you can get used to the pacing.

Remember that you will be given twenty seconds between the initiation of successive trials. Please do not try to see what choices your neighbors are making. Do not indicate by expression or sound how you think you are doing. It is impossible to be right in every case. Remember that it is important to be correct as often as you can.

Are there any questions concerning what you are supposed to do? Be sure to ask me now if you do not understand what you are to do.

We will now proceed with the practice trials. At the completion of these practice trials I will answer any further questions which you may have.

Are there any further questions? Be sure to ask any question which is related to what you are to do if you have any doubts.

APPENDIX III

INDIVIDUAL CUMULATIVE REGRET FUNCTIONS FOR BLOCKS OF FIVE TRIALS

TABLE 1

INDIVIDUAL CUMULATIVE REGRET FUNCTIONS FOR BLOCKS OF FIVE TRIALS
GROUP CC-FF (N = 19)

S BLOCKS											
1	1-10	2.4155	3.4773	3.4773	3.4773	3.8313	3.9725	4.2547	4.2547	4.3958	4.3958
	11-20	4.3958	4.3958	4.6780	4.6780	4.6780	4.6780	4.9602	4.9602	5.1013	5.1013
	21-30	5.2424	5.2424	5.2424	5.9500	5.9500	5.9500	5.9500	5.9500	6.0911	6.2322
2	1-10	1.4588	1.8129	1.8129	1.8129	2.1670	2.8752	2.8752	3.2293	3.7244	3.7244
	11-20	4.2990	4.2990	4.5813	4.5813	4.5813	4.5813	4.8635	4.8635	5.0046	5.0046
	21-30	5.4998	5.8539	5.8539	5.8539	5.8539	5.8539	5.8539	5.8539	5.8539	5.9950
3	1-10	.8842	1.9459	1.9459	2.2999	2.6541	2.7952	2.9363	3.2903	5.0233	5.0233
	11-20	5.0233	5.0233	5.3055	5.3055	5.3055	5.3055	5.8007	5.8007	5.8007	5.8007
	21-30	5.9418	6.2959	6.2959	6.2959	7.1801	7.1801	7.1802	7.1801	7.3212	7.3212
4	1-10	.9567	1.6644	1.8055	2.1595	2.8678	3.0089	3.1500	3.1500	3.2910	3.2910
	11-20	3.2910	3.2910	3.5733	3.5733	3.9274	3.9274	4.2096	4.2096	4.3507	4.3507
	21-30	4.4918	4.8459	4.8459	4.8459	4.8459	4.8459	4.8459	4.8459	5.5616	5.9849
5	1-10	.5746	.5746	.7157	.7157	1.0698	1.2109	1.4931	1.4931	1.6342	1.6342
	11-20	1.6342	1.6342	1.9164	1.9164	1.9164	1.9164	2.1986	2.1986	2.3397	2.3397
	21-30	2.4808	2.4808	2.4808	2.4808	2.4808	2.4808	2.4808	2.4808	2.6219	2.9041
6	1-10	.8842	1.9459	1.9459	2.2999	2.6541	2.7952	2.9363	2.9363	3.7850	3.7850
	11-20	3.7850	3.7850	4.0672	4.0672	4.0672	4.0672	4.3494	4.3494	4.4905	4.4905
	21-30	4.6316	4.6316	4.6316	4.6316	5.5158	5.5158	5.5158	5.5158	5.6569	5.6569
7	1-10	.9567	2.0185	2.0185	2.0185	2.7266	2.8678	3.7520	3.7520	4.2472	4.2472
	11-20	4.2472	4.2472	4.5294	4.5294	4.5294	4.5294	4.8116	4.8116	4.9527	4.9527
	21-30	5.0938	5.4479	5.4479	5.4479	5.4479	5.4479	5.4479	5.4479	5.5890	5.7301

TABLE 1--(Continued)

S Blocks

8	1-10	3.2997	4.3615	4.5026	4.8566	5.5649	6.0600	6.0600	6.0600	6.2012	6.5553
	11-20	7.4840	7.4840	7.7662	7.7662	7.7662	7.7662	8.0484	8.0484	8.0484	8.7560
	21-30	8.7560	8.7560	9.4642	9.4642	10.1718	10.1718	10.1718	10.1718	10.1718	10.1718
9	1-10	.8842	1.9459	2.0870	2.4411	3.1493	3.6445	3.9267	4.2808	4.4219	4.4219
	11-20	4.4219	4.4219	4.7041	4.7041	4.7041	4.7041	4.9863	4.9863	5.1274	5.1274
	21-30	5.2685	5.2685	5.2685	5.2685	5.2685	5.2685	5.2685	5.2685	5.4096	5.8329
10	1-10	.9567	2.0185	2.9026	2.9026	3.2567	3.7520	3.8931	4.2472	4.7424	4.7424
	11-20	4.7424	4.7424	5.0246	5.0246	5.0246	5.0246	5.3068	5.3068	5.4479	5.4479
	21-30	5.5890	5.5890	5.5890	5.5890	5.5890	5.5890	5.5890	5.5890	5.7301	5.8712
11	1-10	.5746	.5746	.7157	.7157	1.4238	1.5650	1.7061	2.0602	2.2013	2.2013
	11-20	2.2013	2.2013	2.4835	2.4835	2.4835	2.4835	2.7657	2.7657	2.9068	2.9068
	21-30	3.0479	3.0479	3.0479	3.0479	3.0479	3.0479	3.0479	3.0479	3.1890	3.6123
12	1-10	.8842	1.2383	1.2383	1.2383	1.5924	1.7334	2.0157	2.9725	3.1136	3.1136
	11-20	3.1136	3.1136	3.3958	3.3958	3.3958	3.3958	3.6780	3.6780	3.8191	3.8191
	21-30	3.9602	3.9602	3.9602	3.9602	3.9602	3.9602	3.9602	3.9602	4.1013	4.3835
13	1-10	.9567	.9567	.9567	.9567	1.6649	1.8061	1.9471	2.3013	2.6554	3.0095
	11-20	3.0095	3.0095	3.2917	3.2917	3.2917	3.2917	3.5739	3.5739	3.7150	4.4226
	21-30	4.9178	5.2719	5.2719	5.2719	5.2719	5.2719	5.2719	5.2719	5.2719	5.2719
14	1-10	.8842	.8842	.8842	1.2383	1.2383	1.3794	1.6616	1.6616	1.8027	1.8027
	11-20	1.8027	1.8027	2.0849	2.0849	2.0849	2.0849	2.3671	2.3671	2.5082	2.5082
	21-30	2.6493	2.6493	2.6493	2.6493	2.6493	2.6493	2.6493	2.6493	2.7904	3.2137
15	1-10	1.4588	2.5205	2.5205	2.8746	3.2287	3.2287	3.3698	3.7239	4.0780	4.0780
	11-20	4.0780	4.0780	4.3602	4.3602	4.3602	4.3602	4.6424	4.6424	4.7835	4.7835
	21-30	4.9246	4.9246	4.9246	4.9246	4.9246	4.9246	4.9246	4.9246	5.0657	5.4890

TABLE 1--(Continued)

S Blocks												
16	1-10	.8842	1.9459	1.9459	2.2999	2.6541	2.7952	2.9363	3.2903	3.4315	3.4315	
	11-20	3.4315	3.4315	3.7137	3.7137	4.0678	4.0678	4.3500	4.3500	4.4911	4.4911	
	21-30	5.3398	5.6939	5.6939	5.6939	5.6939	5.6939	5.6939	5.6939	5.8350	5.8350	
17	1-10	.5746	.9287	.9287	.9287	1.2828	1.7780	1.9191	1.9191	2.0602	2.0602	
	11-20	2.0602	2.0602	2.3424	2.3424	2.3424	2.3424	2.6246	2.6246	2.7657	2.7657	
	21-30	2.9068	2.9068	2.9068	2.9068	2.9068	2.9068	2.9068	2.9068	3.0479	3.4712	
18	1-10	1.4588	2.5205	2.5205	2.8746	3.5828	3.7239	3.8649	4.2191	4.3602	4.3602	
	11-20	4.3602	4.3602	4.5013	4.5013	4.8554	4.8554	4.9965	5.7041	5.8452	5.8452	
	21-30	5.8452	5.8452	5.8452	6.1993	7.0835	7.0835	7.0835	7.0835	7.0835	7.0835	
19	1-10	.8842	2.1225	2.1225	2.4766	3.4052	3.5464	3.6875	4.0416	4.1827	4.1827	
	11-20	4.7573	4.7573	5.0395	5.0395	5.0395	5.0395	5.3217	6.0293	6.7450	6.7450	
	21-30	7.4607	7.4607	7.4607	7.4607	7.4607	7.4607	7.4607	7.4607	7.4607	7.4607	

TABLE 2

INDIVIDUAL CUMULATIVE REGRET FUNCTIONS FOR BLOCKS OF FIVE TRIALS
CP-CC-FF (N = 12)

S Blocks

1	1-10	.0000	.3541	.3541	.7081	1.4164	1.4164	1.4164	1.4164	1.5575	1.5575
	11-20	1.5575	1.5575	1.8396	1.8396	1.8396	1.8396	2.1219	2.1219	2.2630	2.2630
	21-30	2.4041	2.4041	2.4041	2.4041	2.4041	2.4041	2.4041	2.4041	2.4041	2.4041
2	1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	3.1869	3.5409
	11-20	3.8950	4.2491	4.2491	4.2491	4.2491	4.2491	4.2491	4.2491	4.2491	4.2491
	21-30	4.2491	4.2491	4.6032	4.6032	4.6032	4.6032	4.6032	5.4875	5.4875	5.4875
3	1-10	.0000	.3541	.3541	1.0622	1.4164	2.1245	2.1245	2.8321	3.5398	3.5398
	11-20	3.5398	3.5398	4.2473	4.6014	4.9555	5.6632	5.6632	5.6632	5.6632	6.0172
	21-30	6.3713	6.3713	6.3713	6.7254	6.7254	6.7254	6.7254	7.0795	7.0795	7.0795
4	1-10	.8842	2.8301	3.7143	4.4225	6.0149	6.3689	6.5101	6.8642	7.7128	7.7128
	11-20	7.7128	7.7128	7.8540	7.8540	7.8540	7.8540	8.7027	8.7027	9.0568	11.0027
	21-30	11.3568	11.7108	11.7108	11.7108	11.7108	11.7108	11.7108	12.0650	12.0650	12.0650
5	1-10	.0000	.3541	.3541	1.0622	1.7705	1.7705	1.9115	1.9115	2.0527	2.0527
	11-10	2.0527	2.0527	2.3349	2.3349	2.3349	2.3349	2.6171	2.6171	2.7582	2.7582
	21-30	2.8993	2.8993	2.8993	2.8993	2.8993	2.8993	2.8993	2.8993	3.0404	3.3226
6	1-10	.0000	1.2383	1.2383	1.2383	1.9464	2.7958	2.7958	3.1499	3.5040	3.5040
	11-20	3.5040	3.8581	4.1402	4.1402	4.1402	4.1402	4.4225	4.4225	4.5636	4.5636
	21-30	4.7047	4.7047	4.7047	4.7047	4.7047	4.7047	4.7047	4.7047	4.7047	4.7047
7	1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	2.9738	2.9738
	11-20	2.9738	3.3279	3.3279	3.3279	3.6820	3.6820	3.6820	3.6820	3.8232	3.8232
	21-30	4.1772	4.1772	4.5313	4.5313	4.5313	4.8854	4.8854	4.8854	4.8854	4.8854

TABLE 2--(Continued)

S Blocks											
8	1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	3.1869	3.1869
	11-20	3.1869	3.1869	3.3279	3.3279	3.3279	3.3279	3.6102	3.6102	3.7513	3.7513
	21-30	3.8924	3.8924	3.8924	3.8924	3.8924	3.8924	3.8924	3.8924	3.8924	3.8924
9	1-10	.0000	.3541	.3541	.3541	.3541	.3541	.3541	.3541	.4952	.4952
	11-20	.4952	.4952	.6362	.6362	.6362	.6362	.7774	.7774	.9185	.9185
	21-30	1.0596	1.0596	1.0596	1.0596	1.7672	1.7672	1.7672	2.1213	2.2624	2.4035
10	1-10	.0000	1.0616	1.0616	1.7699	2.4781	3.1863	3.1863	3.5403	3.5403	3.5403
	11-20	3.8944	3.8944	4.1767	4.1767	4.5308	4.5308	4.6718	4.6718	4.6718	4.6718
	21-30	4.6718	5.3794	5.7336	5.7336	5.7336	5.7336	5.7336	5.7336	5.7336	6.0158
11	1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	3.1869	3.5409
	11-20	3.8950	4.2491	4.6032	4.6032	4.6032	4.6032	4.6032	4.6032	4.7443	4.7443
	21-30	4.8854	5.2396	5.9477	5.9477	5.9477	5.9477	5.9477	5.9477	6.0888	6.3711
12	1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	3.1869	3.5409
	11-20	3.8950	4.2491	4.2491	4.2491	4.2491	4.2491	4.5313	4.5313	4.6724	4.6724
	21-30	4.8136	4.8136	4.8136	4.8136	4.8136	4.8136	4.8136	4.8136	4.9547	5.3780

TABLE 3

INDIVIDUAL CUMULATIVE REGRET FUNCTIONS FOR BLOCKS OF FIVE TRIALS
GROUP CC-FI (N = 10)

S Blocks

1	1-10	.8842	1.5918	1.5918	2.6534	3.0076	3.1487	3.2898	3.2898	3.4308	3.4308
	11-20	3.4308	3.4308	3.7131	3.7131	3.7131	3.7131	3.9953	3.9953	4.1364	4.1364
	21-30	4.6316	4.6316	4.9857	4.9857	5.8699	5.8699	5.8699	7.6383	7.7794	8.0616
2	1-10	1.8410	2.9026	2.9026	3.2567	3.6108	4.1061	4.2472	4.2472	4.3882	4.3882
	11-20	4.3882	4.3882	4.6705	4.6705	4.6705	4.6705	4.9527	4.9527	5.0938	5.0938
	21-30	5.2349	5.2349	5.5890	5.5890	5.5890	5.5890	5.5890	8.2416	8.3827	8.8060
3	1-10	1.8410	2.9026	2.9026	3.2567	3.6108	4.4601	4.6013	4.9554	5.0965	5.0965
	11-20	5.0965	5.0965	5.3787	5.3787	5.7328	5.7328	6.0150	6.0150	6.1561	6.1561
	21-30	6.6513	7.0054	7.3595	7.3595	9.1279	9.4820	9.4820	9.8361	9.8361	9.9772
4	1-10	.9567	1.3109	1.4520	2.1601	2.5143	3.0095	3.1505	3.5047	4.3534	4.3534
	11-20	4.3534	4.3534	4.6356	4.6356	4.9897	4.9897	5.1308	5.1308	5.2719	5.2717
	21-30	5.8465	6.9082	6.9082	6.9082	7.7924	8.1465	8.1465	8.5006	9.0752	9.0752
5	1-10	1.7684	2.8301	2.8301	3.1842	3.5383	3.6794	3.8205	4.1745	4.3157	4.3157
	11-20	5.2724	5.2724	5.5547	5.5547	5.5547	5.5547	5.8369	5.8369	5.9780	6.3321
	21-30	7.4019	7.7560	7.7560	7.7560	7.7560	7.7560	7.7560	7.7560	9.1793	9.3204
6	1-10	1.4588	2.5205	2.5205	2.8746	3.5828	4.0780	4.0780	4.4321	4.5732	4.5732
	11-20	4.5732	4.5732	4.8554	4.8554	4.8554	4.8554	5.1376	5.1376	5.2787	5.2787
	21-30	6.3485	6.7026	7.4108	7.4108	7.4108	7.7649	7.7649	7.7649	8.4806	8.7628
7	1-10	.9567	1.3109	1.3109	1.3109	1.6649	1.8061	1.9471	2.3013	3.7533	4.7101
	11-20	4.7101	4.7101	4.8512	4.8512	4.8512	4.8512	5.1334	5.1334	5.2745	5.2745
	21-30	6.1232	7.5384	7.5384	7.8925	9.3077	10.0153	10.0153	10.8995	11.7482	12.8791

Table 3--(Continued)

S Blocks											
8	1-10	1.8410	2.5486	2.5486	2.9026	3.6108	4.1061	4.3882	4.3882	4.5294	4.5294
	11-20	4.8835	4.8835	5.1657	5.1657	5.1657	5.1657	5.4479	5.4479	5.9431	5.9431
	21-30	6.4383	7.8535	8.9158	8.9158	9.8000	11.3918	11.7459	11.7459	12.4616	12.7438
9	1-10	.5746	.5746	.7157	1.4238	1.7780	1.9191	1.9191	2.8759	3.7246	3.7246
	11-20	4.2991	4.2991	4.5814	4.5814	4.5814	4.5814	4.8636	4.8636	5.5793	5.5793
	21-30	5.7204	6.4280	7.3122	8.2690	10.0374	10.0374	10.0374	10.0374	10.7531	11.0353
10	1-10	1.7684	2.8301	2.9711	3.8554	4.2095	4.3506	4.4917	4.4917	4.6328	4.6328
	11-20	4.6328	4.6328	4.9150	4.9150	4.9150	4.9150	5.1972	5.1972	5.3383	5.3383
	21-30	5.4794	5.8335	6.1876	6.1876	7.0718	7.0718	7.0718	7.0718	7.2129	7.3540

TABLE 4

INDIVIDUAL CUMULATIVE REGRET FUNCTIONS FOR BLOCKS OF FIVE TRIALS
GROUP CP-CC-FI (N = 12)

S Blocks											
1	1-10	.8842	1.9459	1.9459	3.1842	3.5383	4.0335	4.0335	4.3876	4.8828	5.2369
	11-20	5.5909	5.5909	5.8732	5.8732	5.8732	5.8732	6.0143	6.7219	6.8630	7.2171
	21-30	7.9247	8.2788	8.9870	8.9870	8.9870	9.3411	9.3411	9.3411	9.3411	9.3411
2	1-10	.8843	2.1225	2.8301	3.5383	4.2464	4.9547	5.6623	6.7239	7.0781	7.4321
	11-20	7.7862	8.1403	8.2815	8.2815	8.2815	8.2815	8.9177	8.9177	8.9177	9.2719
	21-30	9.6260	9.9800	10.3341	10.3341	11.2183	11.2183	11.2183	12.1025	12.1025	12.1025
3	1-10	.0000	.3541	.3541	1.0622	1.7705	2.1245	2.1245	2.4786	2.4786	2.4786
	11-20	2.4786	2.4786	2.6198	2.6198	2.6198	2.6198	2.6198	2.6198	2.6198	2.6198
	21-30	3.1150	3.4690	4.1772	4.1772	4.1772	4.5313	4.5313	4.8854	4.8854	4.8854
4	1-10	.0000	1.2383	1.2383	1.9464	2.6547	3.0087	3.0087	3.3628	3.7170	4.0710
	11-20	4.4251	4.4251	4.5662	4.5662	4.5662	4.5662	4.8485	4.8485	5.3436	5.3436
	21-30	5.4848	5.4848	6.5470	6.5470	6.5470	6.5470	6.9012	6.9012	7.0423	7.4656
5	1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	3.3279	3.6820
	11-20	4.0362	4.0362	4.3184	4.3184	4.6724	4.6724	4.8136	4.8136	5.5218	5.5218
	21-30	5.5218	5.8758	6.9381	7.2922	7.2922	7.6464	7.6464	8.3545	8.4956	8.4956
6	1-10	.0000	.3541	1.2383	1.9464	2.3006	2.6547	2.7958	3.1499	3.8575	4.7417
	11-20	5.0958	5.0958	5.2369	5.2369	5.2369	5.2369	6.2267	6.2267	6.2267	6.2267
	21-30	6.9343	6.9343	6.9343	7.2884	7.2884	7.2884	7.2884	8.5267	9.2343	10.7906
7	1-10	.0000	.3541	.3541	1.0622	1.4164	1.4164	1.5575	1.9115	3.2910	3.2910
	11-20	3.2910	3.2910	3.4321	3.4321	3.4321	3.4321	3.5732	3.5732	3.5732	3.5732
	21-30	3.5732	3.9273	3.9273	3.9273	5.6956	6.5799	7.4641	9.2325	9.2325	9.2325

TABLE 4--(Continued)

S Blocks											
8	1-10	.0000	.3541	.3541	.3541	.7081	1.2034	1.2034	1.5575	1.9115	2.2656
	11-20	2.6198	2.9738	3.2560	3.2560	3.2560	3.2560	3.5383	3.5383	4.0335	4.0335
	21-30	4.9622	5.3163	5.6704	5.6704	5.6704	6.6272	6.6272	6.6272	7.7251	8.0073
9	1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	3.1869	3.1869
	11-20	3.1869	3.1869	3.3279	3.3279	3.3279	3.3279	4.0355	4.7432	4.7432	5.0972
	21-30	5.0972	5.8048	6.5131	6.5131	6.5131	7.2206	7.9288	9.6972	9.6972	9.6972
10	1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	3.1869	3.5409
	11-20	3.5409	3.5409	3.8232	3.8232	3.8232	3.8232	4.1054	4.1054	4.2464	4.2464
	21-30	4.7417	5.0958	5.4498	5.4498	6.3341	6.3341	6.3341	6.3341	6.4752	6.7574
11	1-10	.8842	2.8301	2.8301	3.5383	4.2464	4.6005	4.7417	4.7417	4.8828	4.8828
	11-20	4.8828	4.8828	5.0239	5.0239	5.0239	5.0239	5.1650	5.8726	6.0137	6.0137
	21-30	6.8624	7.5700	8.2782	8.6322	9.3399	9.3399	9.6940	9.6940	9.6940	9.8351
12	1-10	.0000	.3541	.3541	1.0622	1.7705	2.1245	2.2656	2.2656	2.6198	2.9738
	11-20	3.3279	3.3279	3.3279	3.3279	3.3279	3.3279	3.4690	4.1767	4.3178	4.3178
	21-30	4.4589	4.4589	5.8747	6.9363	8.3515	9.0591	9.0591	9.0591	9.9079	11.0388

TABLE 5

INDIVIDUAL CUMULATIVE REGRET FUNCTIONS FOR BLOCKS OF FIVE TRIALS
GROUP CC-II (N = 19)

S Blocks											
1	1-10	1.8410	2.9026	2.9026	4.1410	4.4950	4.6362	6.5102	7.8210	7.9622	7.9622
	11-20	7.9622	7.9622	8.2444	9.2012	9.2012	10.0854	10.3676	11.0752	11.0752	11.0752
	21-30	11.6498	13.6396	13.9937	15.0554	16.8238	18.6648	19.3730	20.6113	22.0701	22.0701
2	1-10	1.7684	3.3602	3.5013	4.3855	4.3855	4.3855	5.5519	7.5704	8.5957	8.5957
	11-20	8.5957	9.3033	9.5855	9.5855	9.5855	9.5855	9.8677	10.5753	11.5040	12.5657
	21-30	13.4144	13.7685	14.4761	14.4761	16.0679	16.9521	18.1904	19.0746	19.6492	20.4979
3	1-10	3.6093	5.5553	5.5553	5.5553	5.5553	6.4039	6.5451	8.2095	8.3504	8.3506
	11-20	8.9252	8.9252	9.2074	9.2074	9.2074	10.7992	11.0814	11.0814	11.7971	11.7971
	21-30	12.5128	12.8669	12.8669	12.8669	12.8669	16.7264	20.0872	23.0939	23.8096	23.9507
4	1-10	.0000	1.0616	1.0616	1.0616	1.4157	1.5569	1.5569	1.5569	2.6185	2.9726
	11-20	3.9014	3.9014	4.1836	4.1836	4.5377	4.5377	5.1740	5.8816	6.0227	6.7303
	21-30	7.4460	7.4460	7.4460	7.4460	9.2144	9.2144	9.5685	9.5685	9.5685	9.7096
5	1-10	1.7684	2.8301	2.8301	2.8301	4.0683	4.5636	4.7047	5.0588	5.0588	5.0588
	11-20	5.0588	5.0588	5.1999	5.1999	5.1999	5.1999	5.4821	6.1897	6.5438	7.2514
	21-30	8.8513	8.8513	9.2054	9.2054	10.0896	10.4437	10.4437	11.6820	12.2566	12.5388
6	1-10	.9567	2.0185	2.0185	2.3726	2.7266	3.0808	3.2219	4.5328	4.6738	5.6307
	11-20	6.5593	6.9134	7.0546	7.4086	8.3655	8.3655	8.8606	8.8606	9.2147	9.2147
	21-30	9.9305	10.8592	11.2133	11.2133	11.9208	13.2317	13.2317	13.2317	13.9475	14.0886
7	1-10	.9567	2.0185	2.0185	3.2567	3.6108	4.1061	4.2472	4.2472	4.2472	4.6013
	11-20	4.6013	4.9554	5.2375	5.5916	5.5916	5.5916	6.4404	7.8556	7.9967	9.4119
	21-30	9.9071	10.8358	12.0741	13.1358	14.0200	15.2583	16.1425	16.4966	16.4966	16.6377

TABLE 5--(Continued)

S Blocks											
8	1-10	1.4588	2.5205	2.6615	3.0157	3.3698	3.5108	3.5108	3.8649	5.0678	5.0678
	11-20	5.6424	6.3499	6.6322	6.6322	6.9863	6.9863	8.3302	8.3302	8.4713	8.8254
	21-30	9.8952	10.2493	10.2493	10.2493	11.1335	11.1335	11.1335	11.4876	12.0622	12.2033
9	1-10	1.4588	2.1664	2.1664	2.5205	3.2287	4.0774	4.2185	4.5726	5.7754	5.7754
	11-20	5.7754	5.7754	6.0576	6.0576	6.4117	6.4117	7.1192	8.5345	9.2502	9.6043
	21-30	10.5330	11.5947	11.5947	11.5947	13.3631	13.7171	13.7171	14.0713	14.7789	14.9200
10	1-10	.8842	1.9459	1.9459	2.2999	2.2641	2.7952	2.9363	3.8931	3.8931	3.8931
	11-20	5.0423	5.0423	5.1834	5.5375	5.5375	5.5375	5.8197	5.8197	6.8895	7.5971
	21-30	8.3128	8.8874	9.2415	9.2415	10.1257	10.1257	10.1257	10.1257	10.8414	10.9825
11	1-10	2.7251	3.7869	3.9280	5.8739	7.8643	8.5719	8.5719	9.8828	11.6156	11.6156
	11-20	13.1471	13.5011	13.7834	13.7834	14.1375	15.0217	16.4736	17.1812	17.6765	17.6765
	21-30	19.4539	20.5156	20.8697	23.5958	25.3642	26.3210	27.2052	28.7926	28.9386	30.4950
12	1-10	.9567	2.0185	2.0185	3.2567	5.5568	5.9108	8.3868	8.3868	9.5896	12.5963
	11-20	15.0120	15.3660	15.5072	15.5072	17.6297	18.5139	20.4605	20.4605	21.1762	21.1762
	21-30	22.9091	24.6784	25.5626	25.5626	25.5626	25.5626	26.4468	26.4468	26.5879	26.8701
13	1-10	1.5313	2.5931	2.5931	2.9471	3.3012	3.7964	4.8218	5.1758	6.2376	6.2376
	11-20	8.1230	8.8306	9.1129	9.1129	9.4670	9.4670	10.4568	10.4568	10.5979	11.3055
	21-30	11.4466	11.4466	11.4466	12.7574	14.1727	14.1727	14.1727	14.1727	15.0214	15.3036
14	1-10	2.4155	3.4773	3.4773	3.8313	4.5396	5.3888	5.3888	5.3888	6.5916	6.9457
	11-20	7.2999	7.2999	7.4410	7.4410	7.4410	8.1485	8.4308	9.1384	9.6336	9.6336
	21-30	9.7747	10.3493	10.7034	10.7034	11.4110	11.4110	11.7651	12.1192	12.1192	13.1089
15	1-10	2.4155	3.4773	3.4773	4.3615	4.7156	4.8566	4.9978	5.9545	6.8033	6.8033
	11-20	7.3779	7.3779	7.6601	7.6601	7.6601	7.6601	7.9423	7.9423	8.7916	10.5609
	21-30	10.7020	12.1172	14.0631	17.3193	19.7953	20.5029	22.0953	22.9795	25.6692	26.6590

TABLE 5--(Continued)

S Blocks											
16	1-10	1.4588	2.5205	2.5205	2.8746	3.2287	3.2287	4.2540	5.3157	6.5540	6.5540
	11-20	6.5540	7.2616	7.5438	7.5438	7.5438	8.2514	8.5336	8.5336	8.6747	8.6747
	21-30	9.8775	10.2316	10.5857	12.9577	14.3729	16.9941	16.9941	16.9941	18.0920	19.2229
17	1-10	.8842	1.2383	1.2383	1.5924	1.9464	2.0876	2.2287	2.2287	2.3698	2.3698
	11-20	2.3698	2.3698	2.8650	3.5726	3.5726	3.5726	4.2089	4.9165	5.4117	5.7658
	21-30	6.4815	6.4815	6.8356	6.8356	7.5432	8.4274	8.4274	8.4274	9.4527	9.5938
18	1-10	.5746	.9287	1.0698	1.7774	1.7774	2.2726	3.1212	4.8906	5.9159	6.8001
	11-20	7.1542	7.1542	7.4364	8.1440	8.1440	8.1440	8.4262	8.4262	9.1419	9.1419
	21-30	9.8576	10.4322	10.4322	11.1398	11.1398	12.0240	12.0240	12.7322	12.7322	13.7220
19	1-10	1.4588	2.1664	2.1664	2.5205	2.8746	3.0157	4.1821	4.8897	4.8897	4.8897
	11-20	5.4643	5.4643	5.7465	6.7033	7.6601	7.6601	7.9423	7.9423	8.5169	9.2245
	21-30	9.7991	10.7278	10.7278	12.7463	13.4539	14.4107	14.4107	15.2949	16.8263	16.9674

TABLE 6
INDIVIDUAL CUMULATIVE REGRET FUNCTIONS FOR BLOCKS OF FIVE TRIALS
GROUP CP-CC-II (N = 23)

S Blocks											
1	1-10	1.7684	2.8301	2.8301	3.5383	4.2464	4.3876	4.3876	4.7417	4.8828	5.7670
	11-20	7.6080	7.6080	7.8902	8.5978	9.4820	9.4820	9.7642	9.7642	9.7642	10.4718
	21-30	11.1794	12.4616	14.0540	14.7616	14.7616	14.7616	15.6458	16.5300	17.4142	17.5553
2	1-10	.0000	.3541	.3541	1.0622	1.7705	2.6198	2.9020	3.2560	3.3972	3.7513
	11-20	4.6799	5.0340	5.5293	5.8833	5.8833	5.8833	6.0245	6.0245	7.4484	7.4484
	21-30	8.3770	8.9516	10.0139	10.3680	11.0757	11.0757	12.3140	15.3207	16.2049	16.6282
3	1-10	.0000	.3541	1.2383	1.9464	2.6547	3.3628	3.3628	3.7170	4.0710	4.4251
	11-20	4.7792	5.1334	5.4875	5.8415	6.1956	6.1956	6.5497	6.5497	7.2579	7.6120
	21-30	7.9661	8.3202	9.3825	9.7366	9.7366	10.0907	10.7989	11.5071	11.5071	11.5071
4	1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	3.1869	3.5409
	11-20	3.8950	4.2491	4.6032	4.9573	5.3114	6.1956	6.5497	6.5497	6.9038	7.9655
	21-30	8.3197	9.0272	10.4430	10.7971	11.5047	11.8588	12.5670	14.1594	14.1594	14.1594
5	1-10	.0000	.3541	.3541	.3541	1.0622	1.7705	1.7705	2.1245	2.4786	2.8328
	11-20	3.1869	3.5409	3.6820	3.6820	3.6820	3.6820	3.8232	5.2384	5.7336	7.1487
	21-30	7.6440	7.9981	8.7062	8.7062	8.7062	9.7679	10.1220	10.8303	10.9713	10.9713
6	1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	3.3279	3.3279
	11-20	3.6820	3.6820	3.9643	3.9643	4.3184	4.3184	5.5212	5.5212	6.3705	7.0781
	21-30	7.4321	9.2015	10.9713	10.9713	10.9713	10.9713	11.3254	12.9179	13.4924	13.6336
7	1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	3.1869	3.5409
	11-20	3.8950	4.2491	4.6032	4.9573	5.3114	5.3114	7.4710	9.5938	9.7349	10.0890
	21-30	10.0890	10.4431	11.5054	11.8595	11.8595	12.2136	12.9218	12.9218	12.9218	12.9218

TABLE 6--(Continued)

S Blocks											
16	1-10	.0000	1.9459	1.9459	2.6541	3.7158	5.8391	6.5467	7.6084	7.6084	8.8467
	11-20	10.0850	10.0850	10.5802	11.2878	12.5987	13.4829	13.7652	13.7652	14.6145	16.0297
	21-30	16.9583	17.5329	18.5952	18.9493	19.6569	20.0111	20.7192	22.3117	22.3117	22.4527
17	1-10	.0000	1.2383	1.2383	1.5924	2.3006	3.0087	3.0087	3.3628	3.7170	4.0710
	11-20	4.4251	5.1327	5.1327	5.1327	5.1327	5.1327	5.8403	7.2555	7.9638	9.2021
	21-30	9.5561	9.9102	10.2643	10.6184	10.6184	10.9725	11.6807	12.3889	12.3889	12.3889
18	1-10	.0000	.3541	.3541	1.0622	1.7705	2.1245	2.1245	2.1245	2.4786	2.8328
	11-20	2.8328	2.8328	2.9738	2.9738	3.3279	3.3279	4.3897	5.8048	5.9459	7.3612
	21-30	7.8563	8.9181	9.9803	9.9803	9.9803	10.3344	10.6885	10.6885	10.6885	10.6885
19	1-10	.0000	1.0616	1.9459	2.6541	3.3622	4.0705	4.0705	4.4246	5.4862	5.4862
	11-20	5.8403	6.1944	6.5485	6.9026	7.2568	7.2568	7.6108	7.6108	8.3190	8.6731
	21-30	9.0272	9.3813	10.4436	10.7977	10.7977	10.7977	11.5059	12.2141	12.2141	12.2141
20	1-10	.0000	1.9459	2.8301	5.8376	6.5459	7.6076	7.6076	7.6076	7.7486	7.7486
	11-20	8.3232	8.3232	8.6055	8.6055	8.6055	8.6055	9.1006	9.1006	9.8164	9.8164
	21-30	9.8164	9.8164	10.1705	10.5246	10.5246	10.5246	10.5246	11.2328	11.9485	12.3718
21	1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	3.1869	3.5409
	11-20	3.5409	4.6026	5.3102	7.3287	7.6828	8.3904	8.7445	9.4521	10.1603	11.2220
	21-30	11.5761	12.2837	13.3460	13.7001	13.7001	13.7001	14.0542	14.7624	14.7624	14.7624
22	1-10	.0000	.3541	1.0616	1.7699	2.4781	3.1863	3.1863	3.5903	3.8944	5.2053
	11-20	5.5594	6.6211	7.6828	8.0369	8.3910	9.0986	9.4527	9.4527	9.8068	10.8685
	21-30	10.8685	11.9302	12.9925	13.3466	16.7068	17.0609	17.7691	19.3615	19.3615	19.5026
23	1-10	.0000	.3541	.3541	1.0622	1.7705	2.1245	2.1245	2.4786	2.4786	2.8328
	11-20	3.1869	3.5409	3.8950	3.8950	4.2491	4.2491	5.4519	5.4519	6.1601	7.2218
	21-30	8.2835	8.9911	10.0534	11.1151	12.5303	12.8844	13.2385	14.8309	14.8309	15.1131

TABLE 6--(Continued).

S Blocks											
8	1-10	1.7684	3.7143	3.7143	4.4225	5.1307	5.8389	5.8389	6.1930	6.5470	6.9011
	11-20	7.2553	7.6093	7.9634	8.3175	8.6717	8.6717	9.0258	9.0258	9.7339	10.0880
	21-30	10.4421	10.7962	11.8585	12.2126	12.2126	12.5667	13.2749	13.9831	13.9831	13.9831
9	1-10	.0000	.3541	.3541	1.0622	2.4781	3.8938	3.8938	4.2479	4.6020	4.9562
	11-20	4.9562	5.3102	5.3102	5.6643	6.0184	6.0184	6.0184	6.7260	7.3007	7.3007
	21-30	8.0082	8.0082	9.0705	9.4246	10.3088	10.3088	10.6629	11.3711	11.3711	11.3711
10	1-10	.0000	.3541	1.2383	1.5924	3.0081	3.7163	3.9986	4.7062	4.8473	4.8473
	11-20	4.8473	4.8473	5.1295	5.4836	6.4404	7.1480	7.2890	7.9967	8.9254	9.2795
	21-30	9.2795	10.5617	10.5617	11.8000	12.6842	13.3918	13.7459	14.1000	15.0568	15.1978
11	1-10	.0000	2.4769	3.1844	3.8926	5.3084	5.6625	5.6625	6.0167	6.7242	7.6084
	11-20	7.9625	8.3166	8.8118	8.8118	8.8118	9.5194	10.0147	11.4298	11.7839	12.1381
	21-30	12.4921	13.5538	13.9079	14.2620	14.2620	14.6161	15.3243	16.9167	16.9167	18.3319
12	1-10	.0000	.3541	.3541	.7081	1.4164	1.7705	1.7705	1.7705	2.1245	2.4786
	11-20	2.8328	2.8328	3.1150	3.1150	3.1150	3.1150	3.2560	3.2560	4.3259	5.2101
	21-30	5.2101	5.5642	6.6265	6.9805	6.9805	6.9805	7.3346	8.2188	8.7935	9.2168
13	1-10	.0000	1.0616	4.2453	5.8376	6.5459	8.6693	9.5535	9.9076	11.1459	11.4999
	11-20	11.8541	12.2082	12.7033	12.7033	12.7033	12.7033	12.9856	12.9856	13.7013	13.7013
	21-30	14.0553	14.9841	15.3382	15.3382	15.3382	15.6923	15.6923	16.0463	16.1875	16.1875
14	1-10	.0000	1.2383	2.1225	2.8306	3.5389	3.8930	3.8930	3.8930	4.2470	4.6012
	11-20	4.9552	4.9552	5.0964	5.0964	5.4504	5.4504	6.6533	8.0685	8.9177	9.9795
	21-30	10.3336	12.1029	13.1645	13.1645	13.8721	14.9338	15.6421	16.3502	16.3502	16.3502
15	1-10	.0000	1.9459	2.8301	3.5383	4.9540	6.0158	6.8644	7.2186	7.2186	7.5727
	11-20	8.5014	9.7396	10.0938	10.4479	11.6861	11.6861	12.0402	12.7479	13.1010	13.4560
	21-30	13.8101	14.8718	16.6417	16.9958	17.8800	18.2341	19.8265	20.1806	20.8882	20.8882

TABLE 7

INDIVIDUAL CUMULATIVE REGRET FUNCTIONS FOR BLOCKS OF FIVE TRIALS
GROUP CP-CC NON-FIGURE (N = 25)

S BLOCKS											
1	1-10	.0000	1.9459	2.6534	4.0693	4.7775	5.8391	6.8644	7.9262	8.2802	9.5185
	11-20	9.5185	9.8727	10.2267	12.5261	13.8370	14.7212	15.2164	16.6316	16.9858	18.7550
	21-30	19.1092	20.1708	21.5866	21.5866	23.1784	24.2401	25.4784	27.0708	27.0708	27.2119
2	1-10	.0000	1.7692	1.7692	2.8310	4.2468	5.3084	5.4495	5.8037	5.8037	6.6879
	11-20	8.8830	9.2370	11.1829	11.1829	11.1829	11.1829	12.8473	13.5549	14.0501	17.4112
	21-30	19.3572	19.3572	20.4188	21.1264	21.1264	21.1264	22.7188	23.9571	24.0982	24.8058
3	1-10	.0000	.3541	.3541	.7081	1.7699	2.1240	2.1240	2.4781	2.4781	2.8321
	11-20	3.1863	3.5403	3.8944	4.2485	4.6026	4.6026	4.9567	4.9567	5.8060	6.8677
	21-30	7.2218	8.9911	10.0534	10.4075	10.4075	10.4075	10.7616	10.7616	10.9027	12.3179
4	1-10	.0000	1.9459	1.9459	3.0076	5.3075	6.0158	6.7233	7.0774	8.5295	8.8835
	11-20	9.2376	10.4759	11.5376	12.5993	13.8377	14.5452	14.8993	15.6069	16.3151	17.0227
	21-30	17.3768	17.7309	18.7932	19.1473	19.1473	19.5014	20.2096	20.9178	20.9178	20.9178
5	1-10	.0000	.3541	.3541	1.0622	1.4164	2.1245	2.8321	2.8321	3.1863	3.1863
	11-20	3.7609	3.7609	3.9019	3.9019	4.2560	4.2560	4.3971	5.8124	6.6966	7.0506
	21-30	7.8994	8.9611	10.3768	13.2795	13.2795	13.2795	13.2795	13.2795	13.9952	14.7029
6	1-10	.0000	.3541	.3541	1.0616	1.4157	2.4775	2.6185	3.3261	4.0338	5.2721
	11-20	5.2721	5.6262	6.6879	6.6879	7.9262	8.6337	8.7748	9.4825	9.4825	9.4825
	21-30	10.7646	10.7647	12.1805	13.1372	13.1372	14.1989	14.1989	15.0831	15.7907	15.9318
7	1-10	.0000	1.0616	1.7692	3.0076	3.3617	4.7775	5.4850	5.8391	6.9009	6.9009
	11-20	6.9009	6.9009	7.2550	7.6090	7.9631	8.6707	9.3783	9.3783	10.0865	10.4406
	21-30	10.7947	11.1488	12.9187	13.9804	13.9804	14.3345	15.0427	15.7509	15.7509	15.7509
8	1-10	.0000	.0000	.0000	.3541	1.7699	3.8933	5.4850	5.8391	6.7960	7.1500
	11-20	9.3451	9.6992	9.8404	10.9020	12.1403	12.1403	12.1403	13.5555	14.2637	17.6248
	21-30	17.6248	18.6865	20.4564	20.8105	20.8105	20.8105	22.4029	23.9953	24.7029	25.4105

TABLE 7--(Continued)

S Blocks											
9	1-10	.0000	1.0616	2.6534	4.0693	4.4233	5.8391	6.7233	7.7851	9.7309	10.9692
	11-20	11.3234	12.0310	13.2338	15.6057	16.8440	18.4358	20.4544	21.8695	22.2236	22.5778
	21-30	22.9318	24.3470	25.9394	28.8421	29.5497	31.7448	32.0989	34.5755	35.2831	35.2831
10	1-10	.0000	1.0616	1.0616	2.8310	4.0693	6.1926	6.3337	6.3337	8.3523	3.3523
	11-20	8.3523	9.4139	11.5010	11.8550	11.8550	12.7393	14.7577	16.1729	16.8811	17.5887
	21-30	17.9428	19.7121	20.9504	22.0121	24.3115	24.3115	25.0197	27.1422	28.8066	28.9477
11	1-10	.0000	1.0616	1.7692	2.4769	4.7768	5.1310	6.1563	6.8639	7.8207	9.0590
	11-20	9.4130	9.7672	11.2876	11.6418	11.6418	14.1178	15.4287	16.8439	17.5521	18.9672
	21-30	19.5418	19.5418	21.3117	23.0810	23.0810	24.1428	25.7351	28.2118	28.3528	28.3528
12	1-10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0616	2.1234	2.1234
	11-20	2.4775	4.2468	5.3084	5.3084	5.3084	6.0160	6.3701	7.0778	7.7859	9.5552
	21-30	9.9093	11.6786	12.7409	13.0950	13.0950	13.0950	13.4491	14.1573	14.1573	15.5725
13	1-10	.0000	.3541	1.9459	1.9459	3.0076	5.1310	6.1563	6.1563	8.1747	9.1315
	11-20	11.3266	11.6807	12.3171	12.3171	12.3171	12.3171	14.3355	15.7508	15.8919	18.1912
	21-30	20.1372	21.9065	22.2606	25.1632	27.6392	29.3036	30.5419	31.7803	34.3288	35.0364
14	1-10	.0000	.0000	.1411	.1411	1.2028	2.6185	5.0945	6.1563	6.2974	6.2974
	11-20	7.2542	8.4924	8.7747	8.7747	8.7747	8.7747	10.7932	11.5008	12.3501	13.0577
	21-30	13.1987	14.9681	16.7379	18.6839	18.6839	18.6839	19.3921	19.7461	19.8873	21.3024
15	1-10	.0000	1.0616	1.7692	2.4775	3.8933	4.6009	5.4850	6.5467	6.9009	7.7851
	11-20	8.1392	8.4932	9.5550	10.6166	11.5008	12.2084	12.5626	13.9777	14.6859	16.2777
	21-30	16.2777	17.3394	18.0476	19.1093	19.1093	19.4634	20.7017	21.0558	21.0558	21.9045
16	1-10	.0000	.3541	.3541	1.0622	1.7705	3.1863	3.1863	3.5403	3.8944	4.2485
	11-20	4.6026	5.6643	6.0184	6.3726	6.7266	6.7266	7.0807	7.0807	7.7889	8.1430
	21-30	8.4971	8.8512	9.9135	10.2676	10.2676	10.6217	11.3299	12.0381	12.0381	12.0381

TABLE 7--(Continued)

S Blocks											
17	1-10	.0000	.3541	.3541	1.0622	1.7705	3.1863	4.0705	4.4246	4.7786	5.1327
	11-20	5.4869	5.8409	6.1950	6.5491	8.8168	8.8168	9.1709	9.1709	9.8791	10.2332
	21-30	10.5873	10.9414	12.0037	12.3578	12.3578	12.7119	13.4201	13.4201	13.4201	13.4201
18	1-10	.0000	1.9459	2.8301	4.4225	5.1307	6.9000	6.9000	7.2540	7.6081	7.9623
	11-20		10.2622	10.6164	10.9704	10.9704	10.9704	11.3245	12.7398	13.4479	14.5096
	21-30	14.8637	14.8637	15.5719	15.9261	15.9261	15.9261	17.5184	19.1108	19.1108	19.1108
19	1-10	.0000	.3541	.3541	.3541	.7081	.7081	1.4157	2.1234	2.6185	3.8568
	11-20	4.8136	5.5212	6.6877	7.3953	7.7493	9.1646	9.3057	10.7209	11.5702	11.5702
	21-30	11.9243	12.6319	12.9859	12.9859	13.6935	14.0477	15.2860	16.8783	18.4097	19.2585
20	1-10	.0000	.3541	.3541	.7081	1.9910	2.6991	2.6991	3.0532	3.4074	3.7615
	11-20	4.1155	4.4694	4.8238	4.8238	5.1778	5.1778	5.5319	5.5319	6.2401	6.5942
	21-30	6.9483	7.3024	8.3647	8.7188	8.7188	9.0729	9.7811	10.4893	10.4893	10.4893
21	1-10	.0000	.0000	.0000	.3541	.7081	1.0622	2.6541	4.0693	5.1310	6.3693
	11-20	6.9439	7.6514	8.1467	9.2083	9.5624	12.0385	14.0570	15.4721	15.9674	17.0290
	21-30	18.0908	20.4346	22.3805	23.3373	24.0449	24.7525	25.9909	26.3449	27.2291	28.9265
22	1-10	.0000	1.0616	1.7692	2.4775	2.8316	3.8933	4.7775	5.8391	5.8391	6.7233
	11-20	7.0774	8.6693	9.1645	10.2262	11.1104	12.7022	13.1973	14.6126	15.8508	16.2049
	21-30	16.9126	17.9743	18.6825	20.6283	21.3359	23.3545	24.5928	26.1851	26.8928	27.0339
23	1-10	.8842	1.5918	3.0069	4.0687	5.3070	6.7227	8.4557	9.4125	9.7665	10.6508
	11-20	11.0049	13.6583	14.5425	14.8967	16.7376	18.3295	19.0370	20.4522	21.0268	22.7961
	21-30	23.8579	24.9195	26.5120	27.2195	29.5189	31.5374	32.7757	34.3681	34.3681	35.9244
24	1-10	.0000	1.0616	2.6534	4.0693	4.0693	5.4850	6.3337	7.6446	7.6446	8.5288
	11-20	8.8830	9.9446	10.2987	10.6529	11.5371	12.2447	13.3063	14.0140	14.3681	16.1373
	21-30	16.1373	17.1990	18.2613	18.9689	18.9689	20.0306	20.3847	21.9771	21.9771	22.8258

TABLE 7--(Continued)

S Blocks											
25	1-10	.0000	.3541	.3541	.7081	.7081	.7081	.7081	.7081	.7081	.7081
	11-20	.7081	.7081	.7081	.7081	.7081	.7081	.7081	.7081	.7081	.7081
	21-30	.7081	.7081	.7081	.7081	.7081	.7081	.7081	.7081	.7081	.7081

TABLE 8

INDIVIDUAL CUMULATIVE REGRET FUNCTIONS FOR BLOCKS OF FIVE TRIALS
 FOR SUBJECTS WHO MADE ALL RESPONSES ACCORDING TO THE RESPONSE INDICATED
 BY THE CONDITIONAL PROBABILITIES ON THE FIGURE PRESENTED IN THE EXPERIMENT*

GROUP CP-CC (N = 10)

GROUP CP-CC (N = 33)

Blocks										
1-10	.0000	.3541	.3541	1.0622	1.7705	2.4786	2.4786	2.8328	3.1869	3.5409
11-20	3.8950	4.2491	4.6032	4.9573	5.3114	5.3114	5.6655	5.6655	6.3737	6.7278
21-30	7.0819	7.4360	8.4983	8.8524	8.8524	9.2065	9.9147	10.6229	10.6229	10.6229

*NOTE: Since the cumulative regret function is the same for each subject, the function is presented only once.

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13. ABSTRACT <p>A decision-theoretic analysis and experiment of three related choice situations is presented. The first situation is a standard probabilistic discrimination learning task. Each trial begins with the presentation of one of a set of stimuli. The subject must choose between two response alternatives to predict which of two events will occur on the trial, the probability of each event being a function of the stimulus presented. The second situation arises when the conditional probabilities, i.e., the probabilities of the stimuli given the events, are introduced to the subject at the beginning of the experiment. The third situation is like the second except for the fact that the subject is not told which event occurs on each trial.</p> <p>The decision-theoretic analysis shows what differences in performance would be expected among the three conditions when a strategy which maximizes average payoff is employed.</p> <p>One group of subjects was run in each situation with the overall relative frequency of one event equal to .80. The performance of the subjects in the first and second situations was virtually identical, while the performance of the subjects in the third(non-feedback) was somewhat worse. The performance measure was the sum of the differences between the objective expected payoff of the optimal choices and</p>		

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the choices made by the subject. Comparisons of the choice proportions for the first and second groups indicated that subjects in the second group did not integrate information concerning the overall relative frequencies of events and conditional probabilities. A large proportion of subjects in the third (non-feedback) group made every choice in agreement with the assumption that the overall relative frequency of one event was one-half.

